Rural Energy Planning For The Indian Himalaya

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FOREWORD

This volume represents perhaps the first effort to focus on energy issues in the Indian Himalaya. Much has been written on the ecological and forest problems that have grown over the years in the Himalaya, and while energy problems are at the core of some of these concerns, not much has been done to explain and focus attention on energy issues per se in the region. This book was conceptualized and jointly implemented by the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, and the Tata Energy Research Institute (TERI), New Delhi. Each chapter is based on a state-of-the-art study, authored by professionals in the field.

The chapters presented in this volume have approached energy issues by looking both at the broad geographical characteristics of different sections of the Himalaya region in India, as well as by analyzing technologies, planning issues and regional economic development. Necessarily, the task of putting together such a variety of material and ensuring consistency between different chapters was a complex challenge, but the editors have done a splendid job. Having reviewed the development of this volume at various stages, it is satisfying to observe how changes and modifications have been made at different stages of the writing of each chapter, leading towards an overall logic and consistency of the whole, without diminishing the value of each part.

It is presumptuous, and perhaps an over-simplification, to distil major issues that emerge from a large and varied effort of this nature. But some observations regarding the contributions in this volume are perhaps pertinent. Firstly, the role of energy in economically and ecologically sustainable development in the Himalaya region of India is paramount and requires efforts at every level of government and society. Almost every effort that can be conceived of in developing this region has to come to grips with the energy problem, if development plans and programs are to prove successful. Secondly, the fragility of the mountain ecological system relates to energy problems as well, particularly since mountain communities in India are still overwhelmingly dependent on fuelwood as the major source of energy. Thirdly, the potential for using new technologies based on renewable forms of energy is important as a matter of extreme priority and relevant enough to require a large-scale effort in areas such as dissemination of information and knowhow, development of local institutions to handle these new technologies, and provision of adequate funds.

The major value of this book lies not only in a clear articulation of problems, issues, and possible solutions in mountain development with a focus on the Indian Himalaya, but also in presenting a comprehensive collection of existing information and data on the subject. The authors have brought out in very specific terms the information gaps for further research, demonstration projects, and directions for programs to promote sustainable development of energy resources and their use in the Himalaya region.

A common goal of promoting economically and environmentally sound development in the Indian Himalaya and raising the quality and standards of living is articulated in many ways by the authors. It is hoped that this book will furnish a knowledge base for development planners and administrators, and may help in unveiling new areas of research in mountain energy planning.

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ENERGY IN THE INDIAN HIMALAYA: AN OVERVIEW OF STATUS AND PROSPECTS

T. M. Vinod Kumar and Dilip R. Ahuja

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INTRODUCTION

The Indian Himalaya is a vast chain of mountain ranges exhibiting tremendous agro-climatic, sociocultural and economic heterogeneity. This 0.6 million square kilometer tract of land is home to about 43 million people (1981 census), with an equal number of ruminant farm animals. The Himalaya is richly endowed with sites for the generation of hydroelectricity, just as it was once endowed with forest wealth.

The pattern of energy utilization thus far has been unsatisfactory, as there has been little improvement in the quality of life for the people living in the mountains. Watersheds are being continuously eroded, contributing to floods and siltation. Development of rural energy sources has an important role to play in the satisfaction of basic needs, the augmentation of employment opportunities, and the increase of agricultural and industrial productivity.

This book is an attempt to review experiences in rural energy planning in the Indian Himalaya. The papers have been selected from those commissioned by the International Centre for Integrated Mountain Development (ICIMOD) in collaboration with the Tata Energy Research Institute (TERI) as a part of their program on rural energy planning. Critical gaps in knowledge and experience exist in the formulation of regional energy policies and plans, in orienting energy technologies for Himalayan development, in energy-related institutional development, and in the diffusion of energy technologies. Establishment of a knowledge base was considered the first step in policy research before embarking on more practical work.

The book is divided into four sections, forming a sequence from the specific papers to the most general. A Steering Committee* met with the invited authors in June 1985, to discuss synopses of individual papers and interrelations between the papers.

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* Steering Committee Members:

Shri. J. A. Kalyana Krishnan, then Secretary of the Ministry of Environment and Forest; Dr. J. Gururaja, Director, Department of Non-Conventional Energy Sources; Dr. S. L. Shah, Consultant, Hill Development, Indian Planning Commission; Dr. R. K. Pachauri, Director, TERI; Dr. R. P. Yadav, Deputy Director, ICIMOD; Dr. Dilip Ahuja, TERI; and Shri T. M. Vinod Kumar, ICIMOD.

After these were prepared, they were discussed and revised at a meeting of the authors in Kathmandu, in January, 1986. For the most part, authors speak for themselves; the editors have not supplied caveats.

Energy Technologies for Himalayan Development

In the Himalaya, both humans and cattle need protection from the cold and often they share the same dwelling. The occupation pattern of these buildings shifts depending on the season. **Vinod Gupta** and **Ranjit Singh** describe the traditional architecture of Kashmir, Ladakh, and the Kullu Valley which is effective in retaining heat, but shuts out natural light. The influence of architects and engineers who are insensitive to local building traditions has for the most part been negative, especially from the point of view of energy conservation, mainly due to inappropriate use of building materials and designs. The authors propose solutions that will provide thermal comfort and adequate lighting by utilizing local materials, the wisdom of vernacular architecture and innovative modern designs using materials such as glass and *trombe* walls.

Ashok Gadgil maintains that energy consumption by the people of the Himalaya cannot be increased meaningfully through exclusive reliance on traditional sources of energy such as fuelwood, agricultural residues, and muscular energy. The paper suggests how more energy can be made available to people in this area by new and renewable sources, how current uses can be made more efficient, and waste heat recovered, in the attempt to improve the quality of life. Among new technologies, he discusses the potential of wind power and photovoltaics, especially of amorphous silicon cell technology, for which tremendous reductions in price are anticipated. Enormous scope for saving energy by improving end use efficiency of lighting and heating devices exists. He also describes in detail how passive solar and thermal technologies could be used in architecture, in production of vegetables and biogas, for hot water, and for preservation and storage of foods and medicines. Development needs in each of these areas are stated, along with the advice that for any diffusion effort to be successful, the socio-cultural milieu must be kept in mind.

D. P. Sen Gupta's paper provides a glimpse of the known potential for micro, mini and small hydel sources and documents their sluggish development thus far. He presents cost analyses to show how small hydro projects compare favorably with larger ones, and also with extensions of the grid. The long gestation periods of large hydel schemes involve the lost opportunity cost of capital, generally not included in such comparisons. Making reasonable assumptions, he shows how it becomes uneconomical to extend the grid for distances over 10 km in the hills where potential for small hydel power exists. To further bring down costs, he suggests use of local skills, manpower, and adaptation of designs to suit site-specific conditions. To improve load factors he suggests, among other things, provision of electric connections to low income groups free of charge, and even promotion of the use of electric heat for cooking which will also reduce fuelwood consumption.

The Himalaya belt remains deficient in agricultural production. For various reasons, it has been economical to use either electricity or diesel for lift irrigation. **Dharam Singh** advocates the use of hydraulic rams, which are both cost-effective and easy to operate, to lift water for irrigation and drinking. The cost of a hydram unit ranges as high as Rs.150,000 with a water-lifting capacity of 30,000 gallons per day at lift magnification factors of 4 to 30. Equipment costs, however, are only 15 percent of total costs; the remainder is for civil works. The capital costs are around Rs. 20,000 per hectare of land irrigated. Based on his experiences in the Central Himalaya, the author describes the constraints to more widespread diffusion of this technology.

Factors that have limited the adoption of community-sized biogas plants in the hills include rocky soils, low temperatures, low livestock-person ratios, unavailability of land and water, and the social factors. In fact, only two large biogas plants are functioning in hill districts, these being in institutions. However, the conditions in valleys might not be so adverse. **Sushil C. Agrawal** suggests that the best returns from such systems are obtained when biogas is used for operating village-level industries and that these systems can best be managed by outside agencies. He cautions against premature transplantation of any technology in rural areas.

Energy and People

Based on extensive field experience, **Varun Vidyarthi** recounts factors that constrain or contribute to useful participation in rural energy programs. Villagers tend to be more skeptical about ventures which are based upon the successful organization of the villagers themselves. Other factors that might hinder participation include financial risk and involvement of the outside agency with the existing power structure in the village. For outside agencies this implies considerable involvement of time and resources in working at the village level, to develop local capabilities to ensure that sustained benefits reach the intended target groups. Eventually, the programs need to be managed by the participants themselves, but in the interim period it might be desirable to work through voluntary non-governmental agencies which have the desirable orientation, flexibility, and capability to match current macroconcern to local development requirements.

Padma Vasudevan and **Santosh** describe the various hardships faced by women in energy-related activities in the Himalaya. The out-migration of males to the plains for jobs imposes on women a number of duties that might otherwise be shared. Cooking, fuel collection, and water fetching take the major portion of their time and energy. Child care, agricultural tasks, and animal husbandry also make demands, leaving little time for leisure or remunerative activities. Harsh climate and difficult terrain make their work all the more arduous. Economic status, cultural beliefs, traditional definitions of gender and caste roles, and the degree to which the environment is eroded are some of the major factors influencing the lives of women.

Summarizing surveys conducted in this area, the authors find that great variations exist between households and between villages regarding the fuelwood crisis and perceptions of priority problems. The authors make a plea for introduction of technologies to reduce women's drudgery, and providing home-based employment with the necessary marketing infrastructure.

R. K. Pachauri hypothesizes that a progressively worsening cycle of effects has been initiated by energy scarcity. The increase in time allocated for collection of fuels results in decrease in the production of wage goods and other market activities. With examples from other areas, he shows that macro-economic studies grossly underestimated the non-farm employment provided by secondary forest activities, and that the brunt of curtailment due to deforestation is borne by women. With lower earnings, there is a reduction in household calorie intake which disproportionately affects housewives, who suffer further reduction in the time they are able to spend on productive activities. As a way out of this cycle, the author suggests enhanced availability of renewable energy devices such as biogas, improved stoves, small hydro and solar heating. Since the introduction of these technologies would require the establishment of necessary manufacturing industries and the development of skills to maintain these devices, tremendous employment potential would be generated if this were undertaken along with steps to modernize agriculture.

Regional Energy Status

The four papers in the next section survey the energy situation from a regional perspective. **Manzoor Alam** and **Majid Hussain** describe the physiography of Jammu and Kashmir, and note the extremes in weather condition which make consumption of various fuels in winter twice that of summer. Hydel generation is lowest in the winter, exactly when demand is highest. This has led to excessive reliance on fuelwood as an energy source; about 80 percent of the energy consumed in the state is from firewood. The average per capita consumption is 3.8 quintals per annum of which 1.6 quintals are twigs and branches. The consumption is higher in rural areas than in urban areas, reflecting both the easier availability and possibly the lower efficiency of end use. The urban areas consume more electricity, kerosene, and LPG. The supply of electricity is far short of demand, which the authors claim is retarding the industrial growth and development of the state. Hence, they recommend speedier development of hydro projects and of non-conventional energy sources which would also reduce pressure on forest and lessen ecological degradation.

Using satellite imagery data, **D. D. Pant** and **S. P. Singh** have estimated the land-use pattern in the Central Himalaya; about 22 percent is snowbound, agriculture takes up 14 percent, reasonable forests exist on 20 percent, whereas degraded lands and forests occupy close to 36 percent. Urban areas and grasslands make up the rest. The single major problem they see in this region is the need to revive the forest cover. They feel this can best be done by the replacement of the present crop system as practiced in the hills by a tree-farm system. Looking at a system that includes both the plains and the mountains, they assign a protective role to the mountains and a productive role to the plains, which would take care of the food needs of the hill people. By reducing the biotic stress on existing forests, a tree-farm system would aid in the recovery of even oak forests, which in the middle elevation belt would be rapid. The authors also assess the potential of several renewable energy sources in reducing the pressure on forests and find wind energy and microhydel particularly promising.

Giving details of topography, climate, and population changes in the northeast region, **T. Mathew** sets the stage for descriptions of energy use patterns in the agriculture, industry, and transport sectors. Both the dominance of the use of firewood for domestic energy and the practice of shifting agriculture are leading to deforestation. There is the need for afforestation with fast-growing species. The potential for solar energy seems limited because of extensive cloud cover on most days of the year, but the use of coal in the domestic sector is expected to increase. The region has enormous hydel potential on the tributaries of the Brahmaputra and the Barak, but the author cautions against their rapid development as the region is prone to earthquakes and landslides. Development of microhydel seems to be more economical and has potential to provide power to villages in the shortest amount of time. Besides its use in agriculture, rural electrification holds much promise for improving the quality of life and the promotion of cottage industries and artisan trades.

Nowhere is the nexus between energy and environment as evident as in the tribal societies of the northeast. **P. S. Ramakrishnan**, through extensive research, has found much merit in the shifting agriculture practiced there; it is between 25 and 500 times more energy efficient than modern agriculture and meets the diverse needs of the farmer for cereals, vegetables, tubers, and fibres. Mixed cropping provides an insurance against failure of some crops. The economic return from a 10-year cycle is found to be equal to that from terraced cultivation with modern inputs. However, the life of terraces in the region is only 6 to 8 years on account of heavy rains, whereas shifting cultivation with a 10-year cycle could be maintained indefinitely. Unfortunately, population pressures have shortened the cycle to 4 or 5 years, making it both ecologically and economically non-viable. As a way of reducing pressure on the land to allow more efficient, longer cycles, the author recommends confining cereal cultivation to the valleys, encouraging horticulture and plantation crops on the slopes, and animal husbandry. Only a revegetation strategy could correct the current distortions in tribal societal function.

Energy Planning

J. P. Painuly has scrutinized the existing microstudies and macrostudies on energy consumption patterns in the hill districts of northern India. Microstudies reveal variations in consumption levels and macrostudies reveal that the consumption of domestic energy is between 25 and 70 percent greater in the hills than the rest of the country. The per capita consumption of firewood (obtained at "zero" private cost) is twice the national average, whereas consumption of coal, electricity, LPG, and kerosene are all below the national average. The use of dung for cooking increases moving towards the plains from the hills.

The author projects an increase in total fuel requirements (over 1981 levels) by 41 percent in 1991 and by 128 percent in 2001. If the ABE (Advisory Board on Energy)-recommended per capita consumption of 680 kcal per day per household is to be attained, a threefold increase in present levels would be required. The author presents various options. To increase fuelwood supply is imperative, while substantial increases in the provision of biogas, LPG, electricity, and coal will prove difficult. The efficiency of device end use will have to be improved. A three-tier agency for implementation and monitoring of integrated energy programs is recommended.

In any planning exercise, regionalization is important. This involves identifying areas with relative homogeneity of certain characteristics, which differ from adjoining areas. This can be used both to aggregate or disaggregate units, because the output of this exercise is a hierarchical structure. Depending on whether the characteristics are physical or socioeconomic, regionalization is formal or functional. The regional structure needs to be periodically re-evaluated because of changes in man-environment relationships, and in the objectives for which regionalization is attempted.

The Himalaya display enormous diversity. Nowhere else are small natural regions more sharply separated with respect to structure, height, slopes, and vegetation. **L. S. Bhat** surveys past attempts at formal regionalization and notes that a latitudinal division into the Siwaliks, the Lesser Himalaya and the Greater Himalaya, and a longitudinal division into the Western, Central, and Eastern Himalaya, form the first attempt at disaggregation. It is interesting to note that the southern slopes of the Lesser Himalaya which face the valleys are bare, whereas the relatively inaccessible northern slopes are still covered with thick forests. In a separate exercise in functional sub-regionalization, using demographic and socioeconomic variables, the districts of the Indian Himalaya region have been classified into five developmental regions.

As the traditional methods for compiling resource inventories are of little use for inaccessible regions, Landsat Imagery becomes an important source of data. It has the advantages of offering synoptic views, repetitive coverage and uniformity. **P. N. Gupta** analyzes data related to the population, annual demand, and export of fuelwood, and establishes the main priority for resource planning as the reversal and rehabilitation of badly eroded watersheds. He maintains that remote sensing techniques provide the most rapid and cost-effective method in a number of areas related to energy planning, including identification of priority areas for afforestation, biofuel plantations, preliminary selection of locations for microhydel or other renewable energy sources, and assessing the environmental impact of human activities. In many instances, however, these have to be supplemented with aerial photography and cartographic information for detailed planning.

Micro-experiments in rural energy planning are trials conducted in order to study what happens and to gain new knowledge regarding the contribution of rural energy toward meeting development needs. Macro-application deals with activities for the rapid dissemination of rural energy innovations for production, generation of employment, and for the satisfaction of basic needs for the intended beneficiaries. Because of the current gaps in knowledge, the practice of rural energy planning is indeed an experiment. **T. M. Vinod Kumar** develops a system of regionalization, multilevel energy planning, extension, and implementation for the Indian Himalaya. He sees scope for complementary roles to be played by government, voluntary agencies, academic institutions, and people in rural energy planning and implementation activities in the region.

Looking Ahead

The authors in general support energy-centered development planning efforts, especially at the district level. There are 76 districts in 12 states and union territories in the Indian Himalayas. National energy planning efforts are becoming increasingly refined and many institutions have been developed to deal with problems and issues that arise. State governments usually follow in the steps of the central government; however, most implementation takes place at the district level which is conspicuous for its lack of any such institutions. There is a need to start district planning ventures and incorporate energy as a focus.

Many of the problem areas and issues identified by the authors cannot be resolved in view of the lack of data and secondary sources of information. Furthermore, existing surveys are imperfect and need to be periodically updated and revised. These were identified as major constraints for planning and implementation exercises in the region.

Strengthening decentralized energy planning and management in the Indian Himalaya calls for developing methodologies which have been field-tested in the Himalaya, preparing case study materials for training generalist district-level planners and managers, and above all, nurturing the training capacity of potential training institutions. This has been identified as a second phase program for ICIMOD, to be developed as a regional program for the Hindu Kush-Himalaya.

Section 1 : ENERGY TECHNOLOGIES FOR HIMALAYAN DEVELOPMENT

ENERGY CONSERVATION IN TRADITIONAL BUILDINGS IN THE MOUNTAINS

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INTRODUCTION

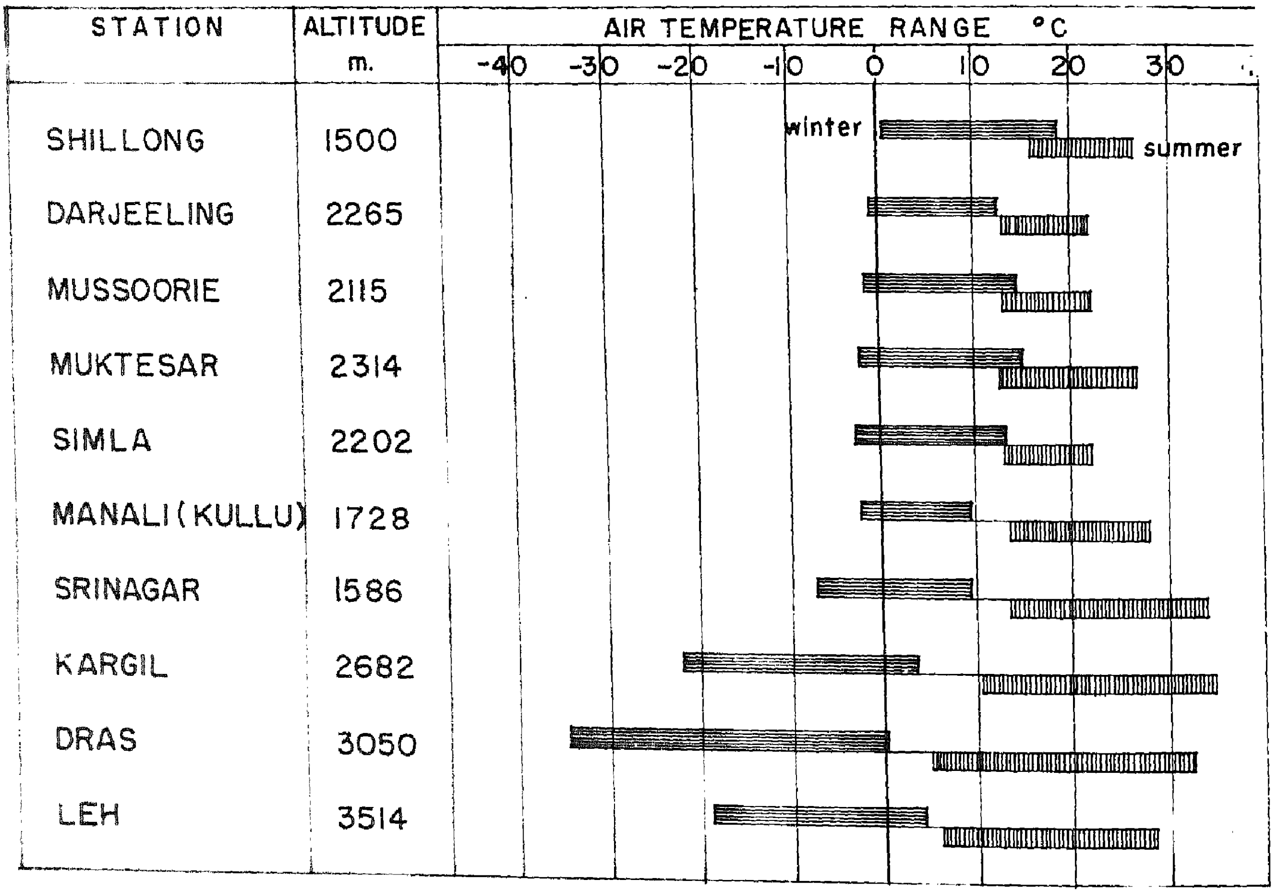
The Himalaya region in India stretches from Kashmir and Ladakh in the west to Arunachal in the east. The climate varies respectively from very cold and dry to humid temperate. As a response to climatic variation and local availability of building materials, many different types of dwellings are found in the mountains. This paper is a study of some of these building responses, suggesting possible improvements in traditional designs.

THE MOUNTAIN MICROCLIMATE

In the plains, climate is determined by temperature, wind, relative humidity, solar radiation, and precipitation. In the mountains, this is compounded by fog and snow, which together with clouds determine the amount of solar radiation available. In the plains, the microclimatic effects cause only minor variations in the general climate, but in the hills, climate depends to a large extent upon local factors and can vary considerably within a few kilometers. Unfortunately, little published climatic data exists for the mountains, and climatic data is recorded regularly in only a few places in the hills (Figure 1). Both the diurnal and the annual ranges increase from Shillong in the east to Dras in the west. There is also a general decrease in temperature as the altitude increases, but as can be seen, Darjeeling is much warmer with an altitude comparable to Kargil. One important microclimatic feature of the hills is the wind, characterized by its velocity and direction. During the daytime as the ground warms up, wind blows up the slopes (adiabatic wind), and at night the direction is reversed (katabatic wind). Both these winds can reach high velocities, particularly along mountain passes, and they can cause considerable damage to buildings and people.

A second important factor is the direction of available solar radiation in mountain areas. Unlike the plains, where the winter sun is always from the south (in the northern hemisphere), on mountain slopes, solar radiation from certain directions gets obscured by other mountains and, therefore, the direction of available sunlight may be east or west rather than south. Steep north slopes get no sunlight at all, while south slopes are ideal for solar radiation. Thus, solar radiation availability varies considerably over short distances, and within an area, the most favorable orientation also changes from point to point.

Because of these great variations in wind and sunlight, building design in the mountains is more site-specific than in the plains, and the builder has to take greater care to make use of favorable



AIR TEMPERATURES FOR STATIONS IN THE INDIAN HIMALAYA FOR TYPICAL WINTER AND SUMMER DAYS (AFTER SESHADRI, 1969)

Figure 1.

elements, while guarding against unfavorable ones. Snow and rain are also important climatic parameters, and a good understanding of local microclimate is needed for an optimum building design.

BUILDING IN THE MOUNTAINS

Transport of materials involves much greater labor in the mountains than in the plains, and because of this, traditional building in the mountains relies almost entirely on locally available materials. The building form is clearly dependent upon available materials also. Thus, one finds flat roofs in Ladakh, and sloping roofs in neighboring valleys. With development of transport facilties in previously inaccessible mountain areas, many new materials have become available in recent years and, as a result,the traditional building form is undergoing a major change. Srinagar in Kashmir Valley is one such area where traditional buildings have almost completely disappeared.

Dwellings in the mountains have to provide protection from the cold winter. Ideally, these buildings should be designed to utilize natural energies--solar radiation in particular--to provide a comfortably warm interior. This has been rarely possible and a heating system, however simple, has been needed in all cases. The main fuel used for heating is wood, which is becoming increasingly expensive as well as scarce. Thus, it is extremely important to conserve heat and thereby conserve fuel also. The one building material that is absolutely essential for preventing heat loss through window openings (i.e. glass) has become available in the mountains only recently. This is the only material that lets sunlight into the building while keeping cold air out. Without glass, a building in a cold region can never be very satisfactory, but as the use of glass in many modern buildings has shown, it is also possible to build unsatisfactory buildings with glass.

Since the purpose of this paper is to look at methods of energy conservation, the discussion will be restricted to the Western Himalaya, as the climate of the Eastern Himalaya is only mildly cold and hardly any energy is consumed there for heating or cooling of buildings. Although there are many regional styles of building in the Western Himalaya also, this paper will deal with three areas: the Kullu Valley, the Kashmir Valley, and the Ladakh region. These three regions have distinct building methods and are reasonably representative of the entire Western Himalaya.

Kashmir Valley

The climate of Kashmir Valley is characterized by a cold humid winter and a slightly warm, humid summer. Rainfall is distributed throughout the year, and during winter there is snow as well. Little variation is found in day and night temperatures, but the annual temperature range is broad, and the summer period becomes uncomfortably warm.

A wide variety of building marterials are available here. These include earth, burnt brick, stone for masonry, timber of many varieties, and thatch. In recent times, galvanized iron sheets, which are not produced locally, have become a commonly used roofing material. Based on the materials used for construction, three kinds of dwellings are commonly seen in Kashmir. The first of these are used by shepherds and are found along the Banihal pass and on mountain slopes. The second type of building is located in villages, while the third and the most complex type is found in the towns.

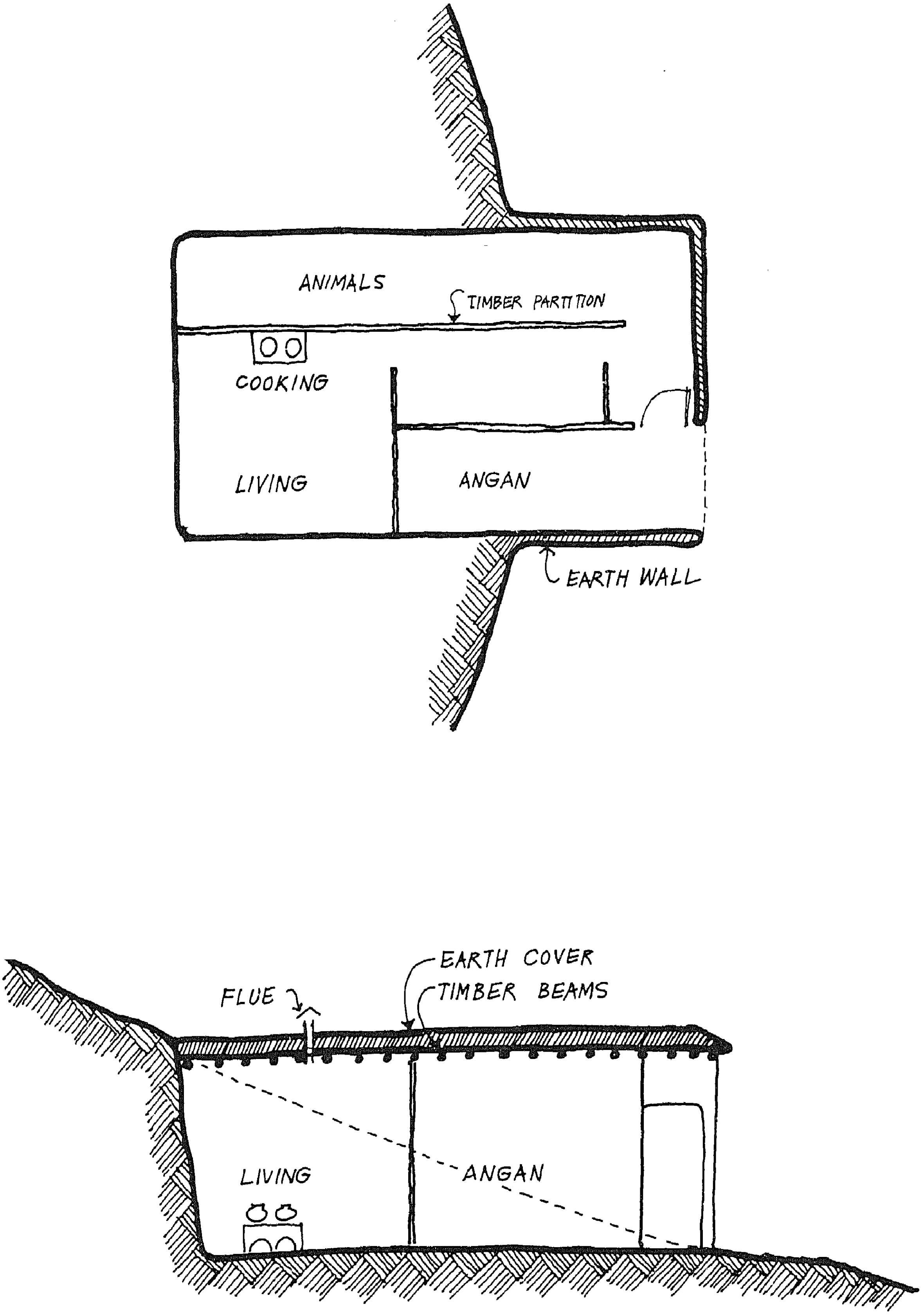
Gujjar (shepherd) house. This simple dwelling is an earth-sheltered structure built entirely from locally available building materials. The building is made by partially cutting into the mountain slope and raising earth walls to enclose a rectangular space. The flat roof is made of earth supported on timber beams. There are practically no openings for windows and only one door which lets in light and ventilation (Figure 2). Such buildings are well equipped to retain heat, but are used mainly in summer. During winter most members of the Gujjar family move to the plains with the cattle.

The house is divided into three parts: a front part where all daytime activities take place (the only part with natural light), one part for cattle, and an innermost part used by the family for cooking and sleeping. The front space acts as a buffer between the external environment and the protected internal space. The doors to the two inner rooms are arranged so there is no possibility for wind to enter. The heat from people, animals, and the cooking stove keeps the living room warm. But with this kind of house there are obvious hygienic problems, as cattle and humans are separated by a thin partition only and light and ventilation are inadequate.

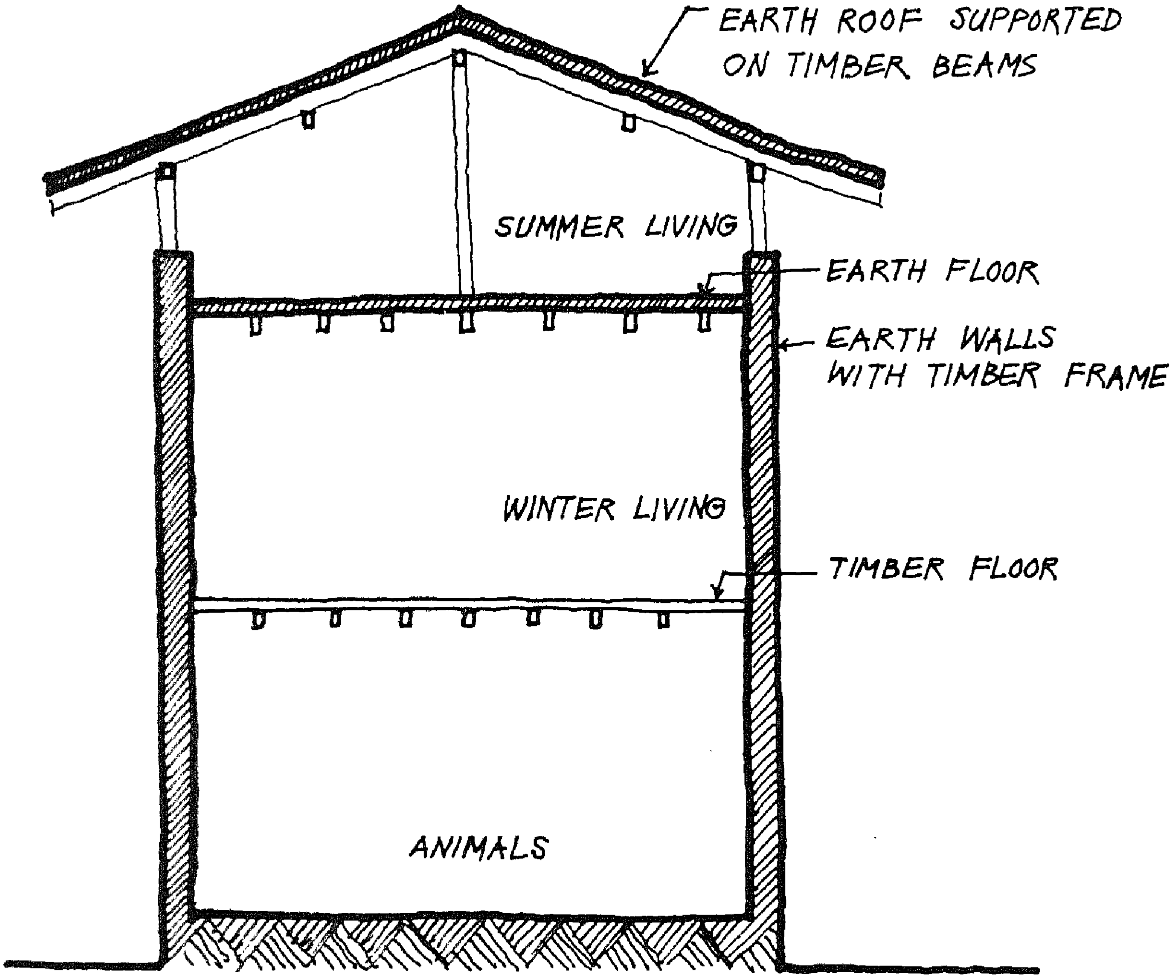
Rural house. Most rural houses are two or three floors high (Figure 3). The materials used for construction of walls and floors are earth and timber, and the main sloping roof over the house is covered with paddy thatch. Occasionally, the sloping roof is covered with earth also. While the two lower floors are fully enclosed with walls, the second floor is open under the gable. The ground floor of the house is invariably used for housing cattle and for storage of fodder, while the first floor is the main winter living room and kitchen. The well-ventilated space under the gable is used for storage of fuelwood.

During winter, the house is kept warm by heat from cattle, which rises to the upper-level living room, as well as by heat from cooking. The massive earth walls insulate the interior space and cold air is kept out by minimizing ventilation. During summers, the household activities of cooking and sleeping shift to the second floor which is well lit and ventilated. This seasonal shift is necessary as the poorly ventilated first floor living rooms become quite uncomfortable in summer.

Urban house. The traditional urban house is usually two stories high, and is better constructed than the rural house. The walls either have a timber frame and earth infill, or random rubble masonry. Even burnt clay bricks are used. The floors are of timber beams and boarding, sometimes covered with earth. Two kinds of roofing materials are used: timber singles or timber boarding waterproofed with birch leaf and topped with a layer of earth on



PLAN AND SECTION -----
GUJJAR HOUSE of KASHMIR
Figure 2.


EARTH ROOF SUPPORTED ON TIMBER BEAMS
SUMMER LIVING
EARTH FLOOR
EARTH WALLS WITH TIMBER FRAME
WINTER LIVING
TIMBER FLOOR
ANIMALS

RURAL HOUSE - KASHMIR

Figure 3.

which irises can be grown in summer. The second type of roof was the more common one, but has been replaced by galvanized iron sheeting in recent years. Urban living requires the houses to be better lit than in the villages, and therefore the rooms have an adequate number of windows. Earlier, when glass was not available, the windows were fitted with timber shutters (sometimes lattice work), which was covered with translucent oil paper in winter.

The ground floor of the house has the *hammam* (heated living room) and the cooking and dining areas. The upper floors are used for sleeping and other household activities. The windows are placed in the south wall to let in the sun. The house was previously heated by the *hammam* under the floor heating system. This consumed a great deal of timber and, in the last few decades, has been replaced by the more efficient *bukhari* (a stove placed in the living room itself). Although an improvement over the ancient system, the current *bukharis* are still very inefficient when compared to, for instance, closed metal radiant woodstoves in the U.S.A. Their efficiency can be greatly improved.

This type of building conserves energy by reducing air infiltration through windows, by good insulation in the thick earth roof and walls, and by accomodating daytime activities in the sunny part of the house. Because such a house could become quite uncomfortable in summer, the oil paper is taken off the windows to let in more air, and as in the case of rural houses, the family moves up to the better ventilated part of the house.

Artificial heating. With good building design, it is possible to reduce heat loss through the building envelope, but this does not always ensure comfortable conditions inside the house. However, in Kashmir the main emphasis is on keeping people warm and not on house heating. For this, the Kashmiris have developed a very warm baggy dress called *pheran* which covers the body from head to toe, and a portable personal heater called *kangri*. This remarkable heater is actually a small charcoal brazier, which is carried under the *pheran*. The heat from the *kangri* warms the air enclosed by the *pheran*, keeping the person warm even outdoors. This would be a very good low energy-consuming heating system, were it not for the many health and safety problems associated with it. The *kangri* is carried very close to the skin and people even sleep with a burning *kangri* between their legs. Despite good training, which Kashmiris receive at a young age, sometimes *kangris* do overturn, causing fires, but much worse is the occurrence of cancer of the thighs because of prolonged use of a *kangri*.

Kullu Valley

The climate of Kullu Valley is different from that of Kashmir, and temperature variation is greater. There is less moisture in the air, but more snow, and the valley is windier. The winds flow along the river Beas as well as up and down the slopes on either side of the valley (Figure 4). These winds can be very sharp.

The occupational pattern in Kullu is not entirely different from that of Kashmir.

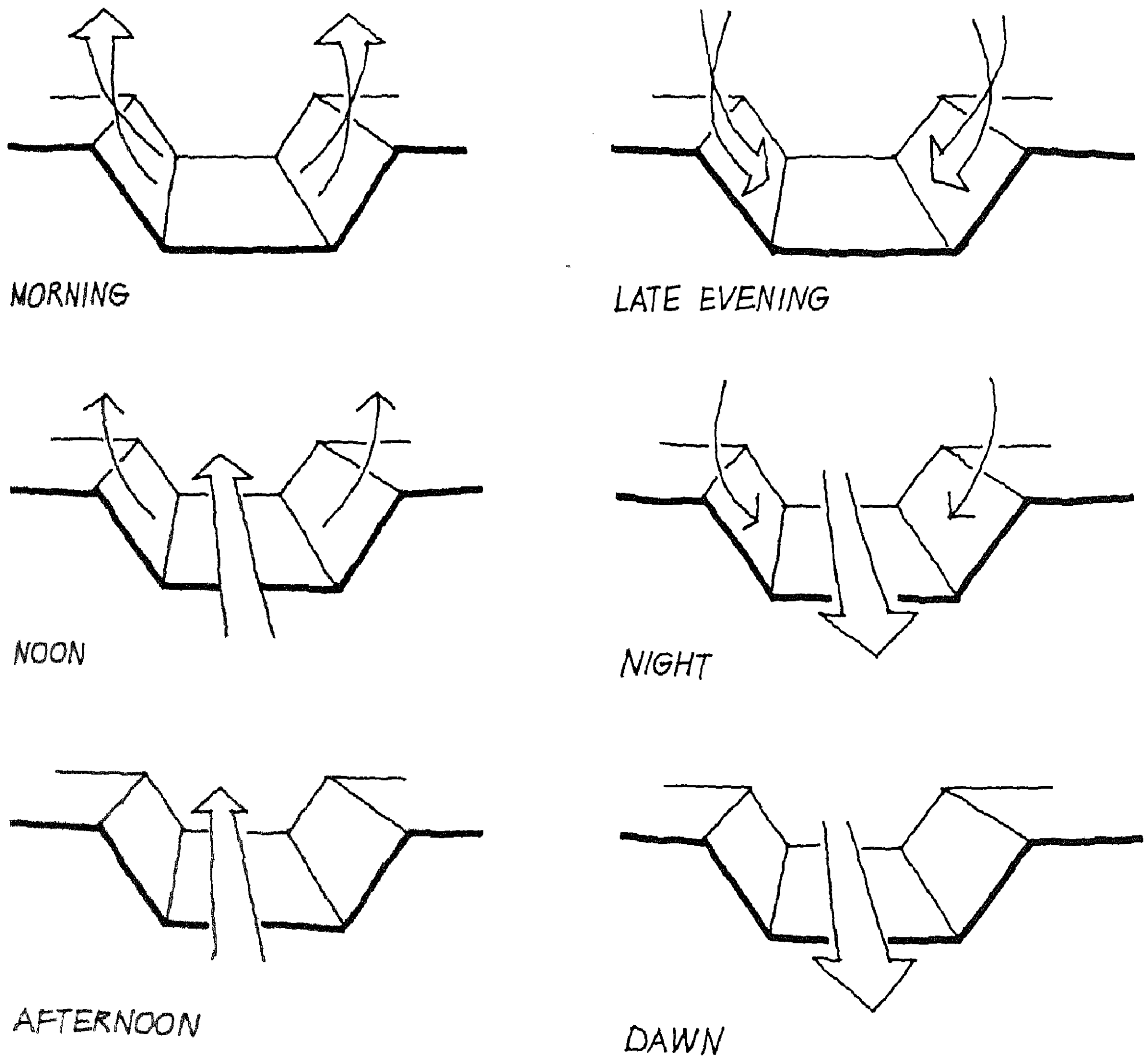


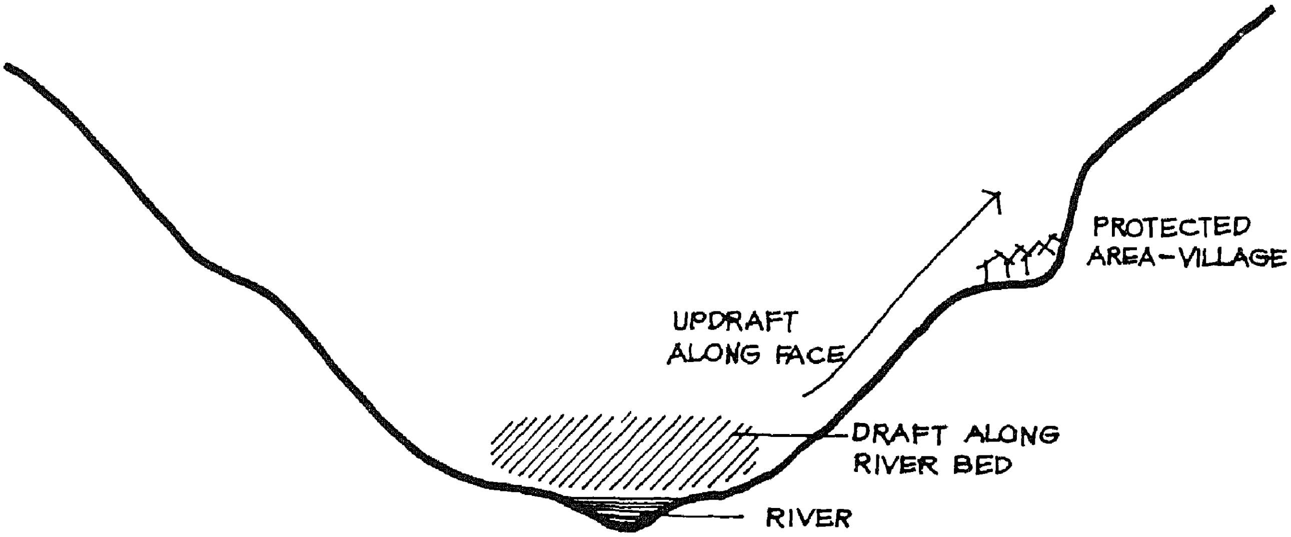
Fig.- 4
WIND FLOW DUE TO SLOPES (AFTER WATSON, 1983)

Figure 4.

In addition to agriculture, people practice horticulture. Since fuelwood is available in plenty, its collection does not involve as much time and effort as in Kashmir, and people have more time to spend on activities like weaving. Therefore, not only is shelter needed from cold and wind, but also the buildings must provide a warm and well-lit space for weaving.

The Kullu Valley has a variety of natural building materials available. Stone for masonry and slate for roofing can be obtained easily from nearby areas. There is no dearth of good building timber also.

Building system and planning. Planning for protection from cold begins with the setting of the villages themselves. Basically, the location has to be such that water is easily available, there is plenty of sunshine, and there is some protection from the cold winds. In view of these requirements, no village is ever located on a north slope and in the Kullu Valley which runs north-south, and there are more villages on the eastern side than on the western side because the former gets more sun in the afternoon when the sky is clearer. The villages are located well out of reach of the river and the cold winds that flow along it, and are tucked away in flatter areas on the mountain slope (Figure 5). This location gives protection from the winds that blow during the daytime, but other means are needed to protect the houses from the descending winds at night.



VILLAGE LOCATION IN KULLU VALLEY

Figure 5

The house. Because of snow and rain, the houses in Kullu Valley have pitched roofs (Figure 6). The main building is built of stone rubble masonry and floors of earth supported on timber beams. On the first and second floors, the stone structure is surrounded by a lighweight balcony of timber. Usually there is a high plinth and the slate roof projects beyond the balcony. As in Kashmir, the ground floor is used for housing the milk cattle and for storage of fodder. During the winter, the kitchen is located at the first floor level and the family spends most of its time around the smokeless cooking stove. The balcony at this level has various uses. On the sunny side of the house, the balcony is used for sitting and working in the well-lighted area, while on the north and the non-sunny side, the balcony becomes a store for wood and for fodder. On the shaded side, the balcony is also completely shuttered so that the main house is protected from the cold winds that come down the mountain slope. During the more active summer season, the kitchen moves up to the attic, where there is a smokeless cooking stove.

Thus the special design features of the house are:

- There is a healthy respect for sun; the houses are located so there is plenty of sunshine on the balcony and in the drying yard around the house.

- The main living area of the house is kept warm by the heat from the cooking stove and by the body heat of humans and cattle. The heat is retained by insulating the north side and the darker side (east or west) of the house.

- In the absence of glass for windows, it is difficult to use solar radiation for heating of the house, but the houses are oriented so sunlight is available to sit in and for drying activities in and around the house.

Ladakh

The climate of Ladakh is very cold and dry with only about 238 mm annual precipitation. Even snowfall during the winter is meagre. The area is almost completely devoid of vegetation and may be classified as a cold desert. Due to the absence of moisture, the sky is usually clear and solar radiation is intense. The nights are cold throughout the year, but summer days are usually warm. This type of climate demands that the buildings be able to even out the temperature differences between day and night.

Because Ladakh has remained isolated, it has been necessary for people to build houses using only locally available materials and skills. Timber is in short supply and even good building stone is not easily available. The one abundantly available material is earth, and this is the principal building material for walls, roofs, and floors. In the dry climate of Ladakh, compacted earth walls are durable, and the mud-plastered surface requires little maintenance as there is hardly any rainfall. In fact, mud walls are used not only for houses but also for more important buildings like monasteries. It is not unusual to see three or four storied mudwall structures in Ladakh, and some even higher. Roofs are generally flat and are constructed with earth supported on a framework of

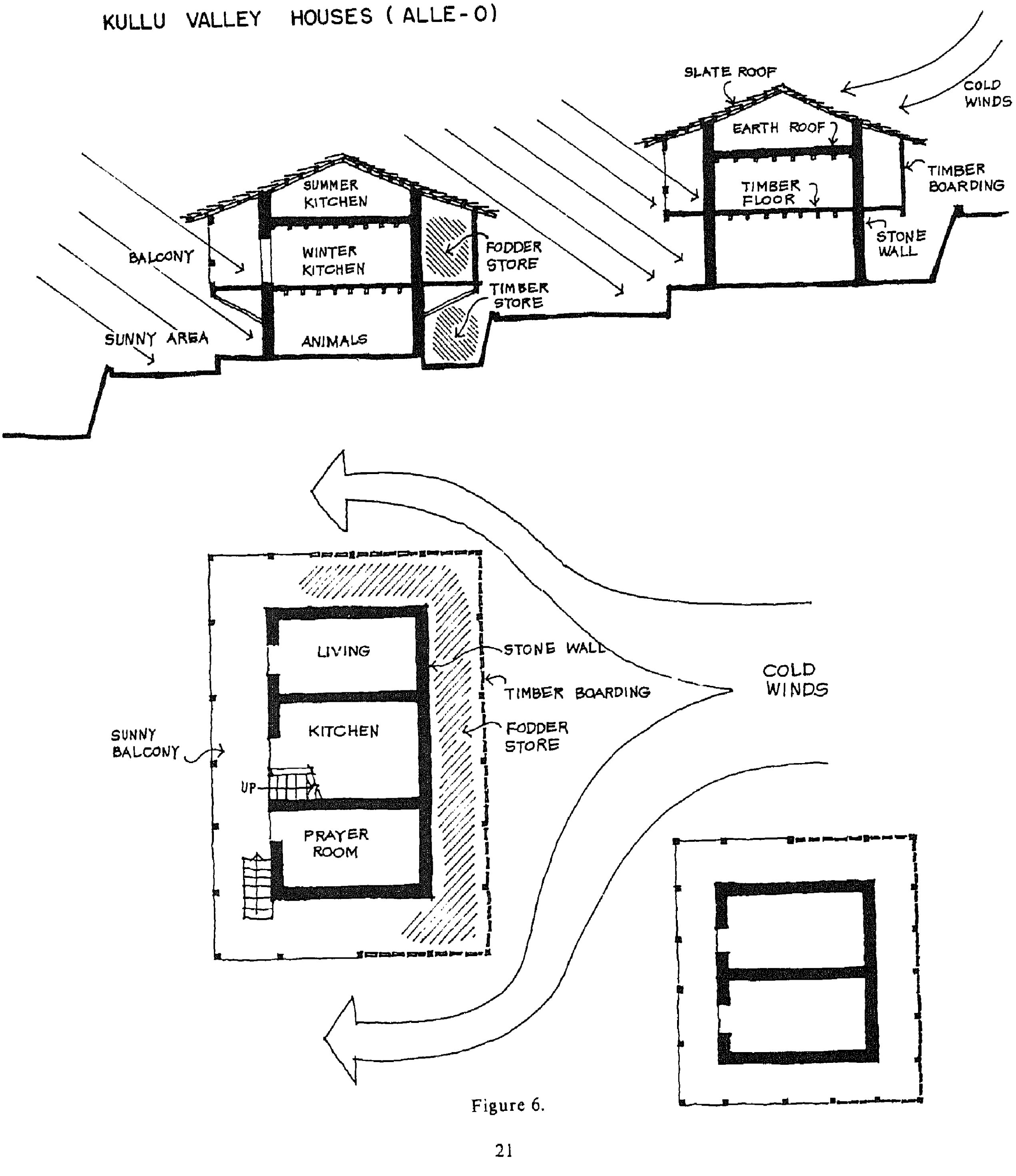

KULLU VALLEY HOUSES (ALLE-O)
SLATE ROOF
COLD WINDS
EARTH ROOF
TIMBER BOARDING
TIMBER FLOOR
STONE WALL
SUMMER KITCHEN
WINTER KITCHEN
BALCONY
FODDER STORE
TIMBER STORE
SUNNY AREA
ANIMALS
LIVING
STONE WALL
TIMBER BOARDING
COLD WINDS
KITCHEN
FODDER STORE
SUNNY BALCONY
UP
PRAYER ROOM

Figure 6.

timber beams. This is done simply in houses, but takes elaborate forms in the monasteries.

The house. The typical house of Ladakh is two stories high (Figure 7). In this extremely cold climate, even cattle may not venture out in winter, and they occupy the lower floor of the house. Sometimes there is an enclosed yard on the ground floor where cattle can sun themselves. During winter, the family lives on the first floor and the kitchen is the main living room of the house. This is also where the family sleeps.

Usually there is a smokeless stove in the kitchen so it is possible to stay in this room even when cooking is going on. The few existing windows are small. Since glass was not available in Ladakh until recently, windows are fitted with solid timber shutters which give one the choice of letting in light as well as cold air, or of keeping both out. The window openings are limited to the sunny sides of the building, and the sides exposed to cold winds have no openings at all.

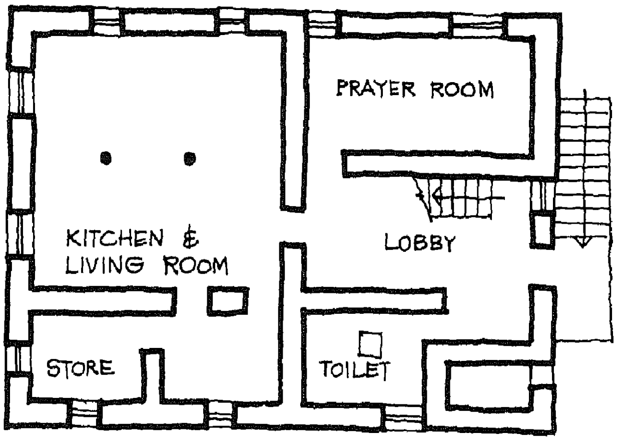
Because of sub-zero temperatures in winter, the family stays inside most of the time. A large quantity of fuelwood is required for cooking and heating during winter, and this is normally gathered during the warmer summer months and stocked on the roof of the house. This layer of wood adds to the insulation value of the roof. During summer, the well-insulated and poorly ventilated house can become uncomfortably warm, and the typical Ladakhi family shifts its activities, including cooking and sleeping, to the roof. Sometimes cloth awnings are erected over the roof for shade from the fierce sun.

Thermal comfort. During January, the coldest month of the year, the indoor temperature of the unheated house falls below the freezing point, and even during the milder winter months the temperatures are far from comfortable (Figure 1). Thus, some space heating is definitely needed and this is usually done by the smokeless cookstove or *bukhari*. The typical Ladakhi family spends the whole summer gathering fuelwood for use in the stove during winter.

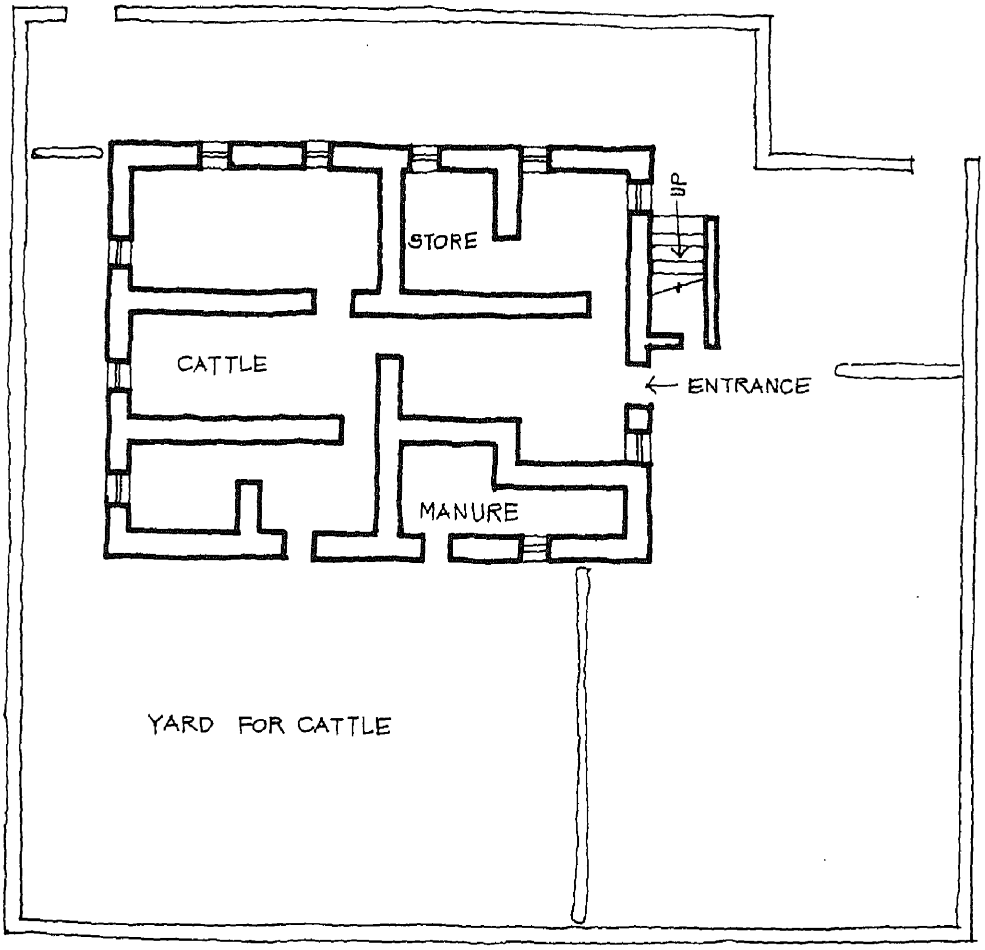
MODERN BUILDINGS

As mentioned earlier, glass is now available in the mountains along with several other new insulation materials. For the general population, however, these imported materials remain quite expensive and, with the exception of glass, their use has been limited to public buildings. It has been shown by experiments in Leh (Gupta 1981) that glass can be used effectively for solar passive heating of buildings, but more commonly it is seen that this new material is not used judiciously so the resulting buildings are thermally inferior to the unglazed ones, though they may be better lit.

While many traditional buildings are carefully designed with respect to solar orientation, buildings are usually constructed according to local custom based on religion. Thus, Muslim houses in the Kashmir Valley have openings toward the west (Mecca) even though they are not efficient thermally. These days, buildings are being constructed for educational facilities, hotels, factories, and other functions which did not exist earlier. These buildings are designed by



UPPER FLOOR PLAN



LOWER FLOOR PLAN

LADAKH HOUSE. (AFTER KHOSLA, 1984)

Figure 7.

architects and engineers who are rarely sensitive to and aware of the local practices. In any case, the rules for house planning cannot be applied to other types of buildings. Therefore, it is not uncommon to find buildings in the mountains that are similar to their counterparts in the plains and have almost nothing to do with an appropriate design for the mountains. Often technology and materials from the plains are used in the mountains, resulting in poorer buildings.

In the Kashmir Valley, the traditional roofing material was earth supported on timber beams, and usually a timber false ceiling was also provided in the house. Since galvanized iron sheets were introduced in Srinagar, earth roofs have been gradually replaced to the extent that they have all but disappeared. The galvanized iron sheeting did solve the problem of roof waterproofing. It also enabled sharper pitched roofs so that snow could slide off by itself, but this roofing material has little insulation value. Add to this indiscriminate use of glass in walls and we have a prescription for buildings that are hot in summer and cold in winter. Of course, galvanized iron roofs can be insulated with a variety of materials and the insulation value of glazed walls can be improved by use of double glazing, but these are rarely used in Kashmir. As a result, newer buildings require more heating than traditional buildings. Thus, one can say that people in urban areas are willing to sacrifice thermal comfort (and energy savings) for the sake of convenience. This is not necessarily so in the rural areas where life still moves at a slower pace and time is available for building maintenance.

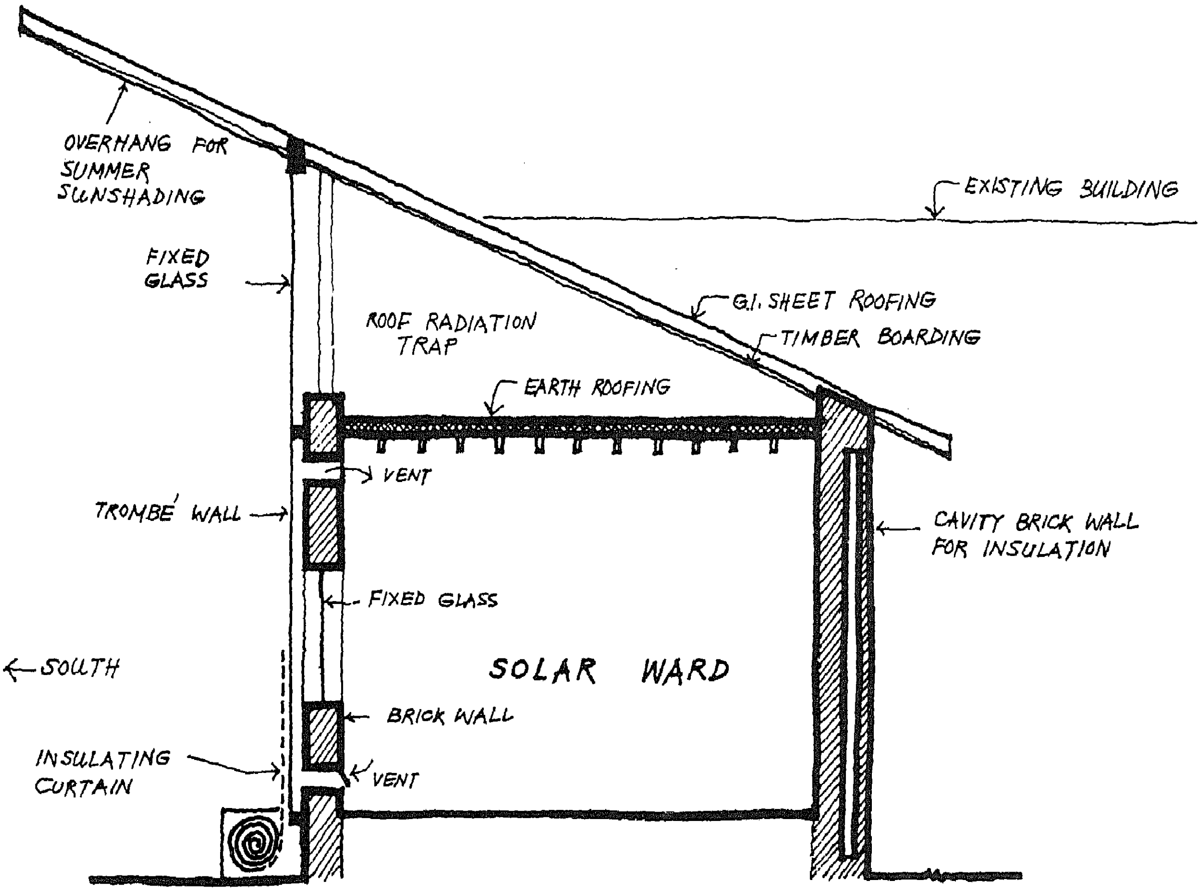
From the point of view of development, it is necessary to find appropriate building methods that combine the benefits of old and new materials. In the case of roofing, for example, it is possible to use earth for its insulation value and galvanized iron sheets for waterproofing. Such a roof is being used for a solar-heated dispensary in Srinagar, where galvanized iron sheeting is the external sloping weatherproof covering and a flat earth roof is the insulating false ceiling (Figure 8). This is very similar to the roofing used in certain parts of Himachal Pradesh and not very different from the traditional roof of rural houses in Kashmir. Its performance can be further improved by placing insulation under the galvanized iron sheets and by glazing the south-facing attic wall to form a roof radiation trap (Givoni et al 1976).

Energy Conservation and Space Heating

Energy for heating of buildings can be conserved by:

- Retaining heat within the building
- Admitting ambient heat into the building
- Using an efficient space-heating system

The first of these requires the building shell to be well insulated and all openings to be made airtight. The objective is to reduce conduction heat loss through the walls and the roof and to reduce infiltration heat loss which normally occurs through cracks around window and door shutters. Modern building materials like fiberglass or



SOLAR HEATED ADDITION TO DISPENSARY AT SRINAGAR

Figure 8

rockwool blankets, expanded polystyrene and polyurethane foam can be combined with any kind of wall or roof construction to improve the insulation value. These can be applied to existing buildings also. Reduction of infiltration heat loss is a little more difficult as it requires substantial improvement in the quality of construction of doors and windows. Inexpensive rubber gaskets can be used to ensure tighter seals but these are not popular because they need to be replaced intermittently.

Building shape and orientation also determine heat loss. Compact buildings have less external surface area than extended building forms and since heat loss occurs only through external surfaces, the former lose less heat than the latter. Wind action results in increased heat loss through external surfaces and infiltration. The windier sides of the building should therefore be sheltered and without openings as far as possible. Earth embankments on the windier side can help streamline air-flow and thereby reduce heat loss through the walls. Not all parts of the building require equal heating. Bedrooms and living areas have to be warmer than storerooms or passageways which can consequently be used as a buffer between the warm living areas and the cold outdoors.

In the cold climate of mountain areas, the only ambient source of heat is sunlight and the buildings must be built to admit as much sunlight as possible. Glazed openings allow sun to come into the building while keeping the warm air in. But ordinary single glass has poor insulation value so glazing has to be insulated with the help of curtains, blinds, or some other kind of shutters. The distance between buildings, the shape of buildings, and their orientation with respect to the sun has to be carefully regulated to ensure that one building does not shade the windows of another. The temperature can be controlled and maintained within the comfort limits by using one or more of the solar passive heating systems described below.

Despite good design, some heating is usually necessary. The ordinary fireplace is quite inefficient as a space heating device, as heat escapes through the chimney. Fully enclosed stoves with a considerable length of flue pipe within the heated space are more efficient and fuel conserving. Many new designs for such stoves are now available.

Solar Heating

Energy savings are possible by use of solar passive space heating. As distinct from active solar heating systems, passive systems use a minimum of mechanical equipment, with the building itself being designed and used as a large solar collector. Essentially, all solar heating systems require a south-facing surface that receives sun throughout the day, a way of trapping or collecting the solar energy, and a method of storing and distributing the heat.

The three potentially applicable systems are:

- Direct gain
- Greenhouse or solarium
- *Trombe* wall

The first is simply a large, south-facing window, possibly with an insulating shutter for use at night (Figure 9). This is the system most commonly used, but it usually results in temperatures too high during the daytime and too low at night. It is useful for buildings such as offices and factories that are used only during the day but of lesser use in houses. The greenhouse or solarium, as the name implies, is a glasshouse attached to the main building. While the sunshines, the greenhouse heats up and slowly warms the main building by convection. Once again, an insulating shutter over the glass is desirable for use at night. This system ensures somewhat better control of heating and less temperature fluctuation. Its major advantage is the addition of a pleasant and sometimes profitably useful space to the house.

The system that gives the best control over heating is the *trombe* wall. In its simplest form, this is a south-facing masonry wall painted black, to which a glass cover has been added. Solar heat is absorbed by the black surface and it gets into the building slowly through the masonry wall. In more complicated versions of this system, vents are placed in the masonry wall to allow circulation of air between the cavity and the room, thus bringing heat into the room early in the day. This system has been found useful in Ladakh, and since its introduction in 1979, many residents of Leh have added *trombe* walls to their houses. In the reported thermal performance study (Gupta 1981), two small single-storied buildings with *trombe* walls were compared to normal buildings and it was found that, during mid-winter, the temperature in the solar-heated buildings was higher by 8° to 12°C (Figure 10). This represents a great improvement in indoor environmental conditions in Ladakh. It was calculated that in case the buildings were to be heated to a constant temperature of 18°C, solar heating would provide one-third to three-fourths of the fuel needs. It was also calculated that for a 30 m^2 house, 5.7 tons of fuelwood or 992 liters of kerosene would be saved every winter. Ladakhis usually heat their houses to less than 18°C and therefore the actual savings of fuel would be less, but then solar heating will provide for even more than two-thirds of the heating fuel.(Table 1)

CONCLUSIONS

Much improvement is desirable in the planning, design, and construction of new buildings in the mountains in order to conserve fuel and to provide better thermal comfort. New materials, designs, and construction techniques can help in realizing this goal.

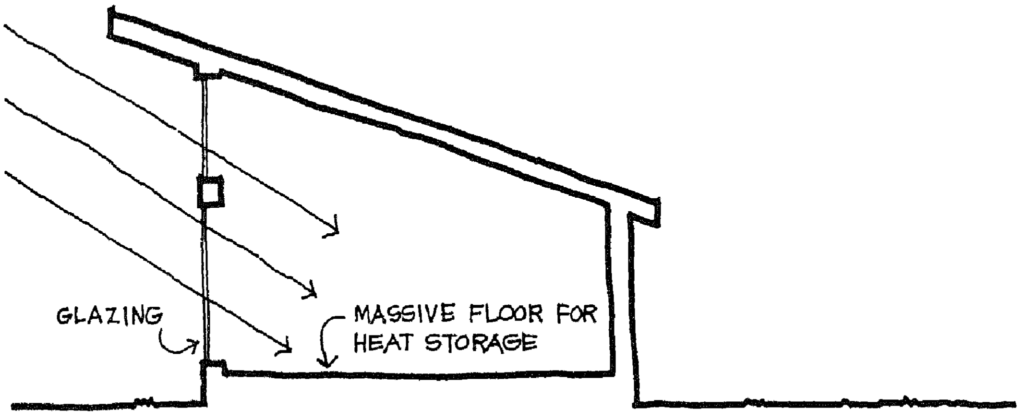
It is necessary to:

- Construct model buildings to demonstrate new techniques

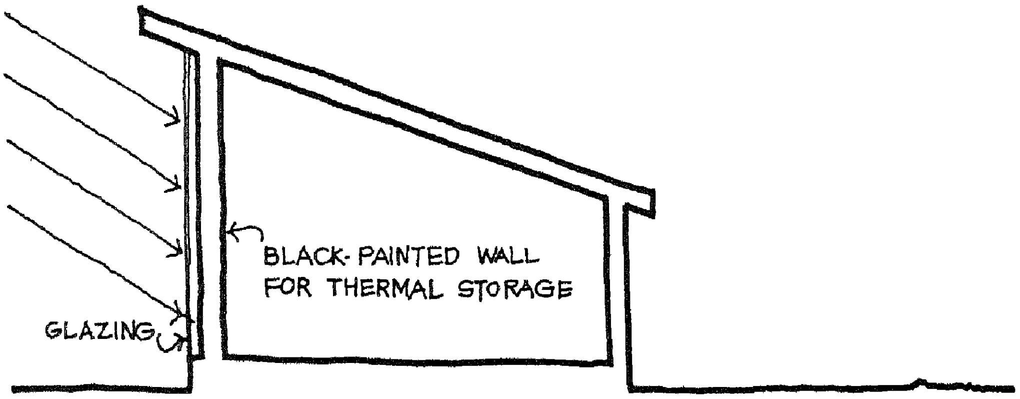
- Undertake studies to evaluate the effectiveness of the new techniques

- Organize training programs for architects and engineers who build in the mountains to expose the architects to the useful aspects of traditional buildings, the use of new buildings materials, and the use of solar energy for heating

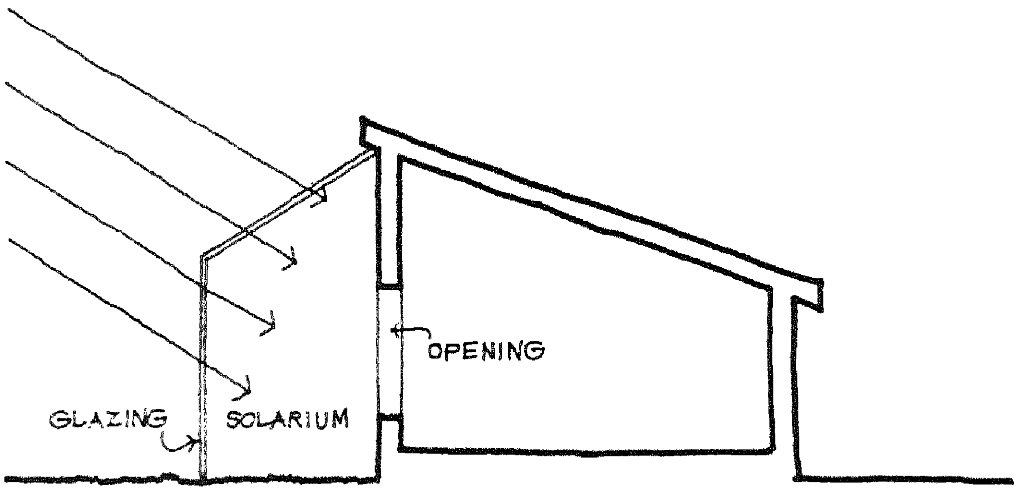
Even though traditional buildings are energy conserving, improvements are desirable in the indoor environment of these buildings. Specifically, the use of new material for insulation and glazing



DIRECT GAIN

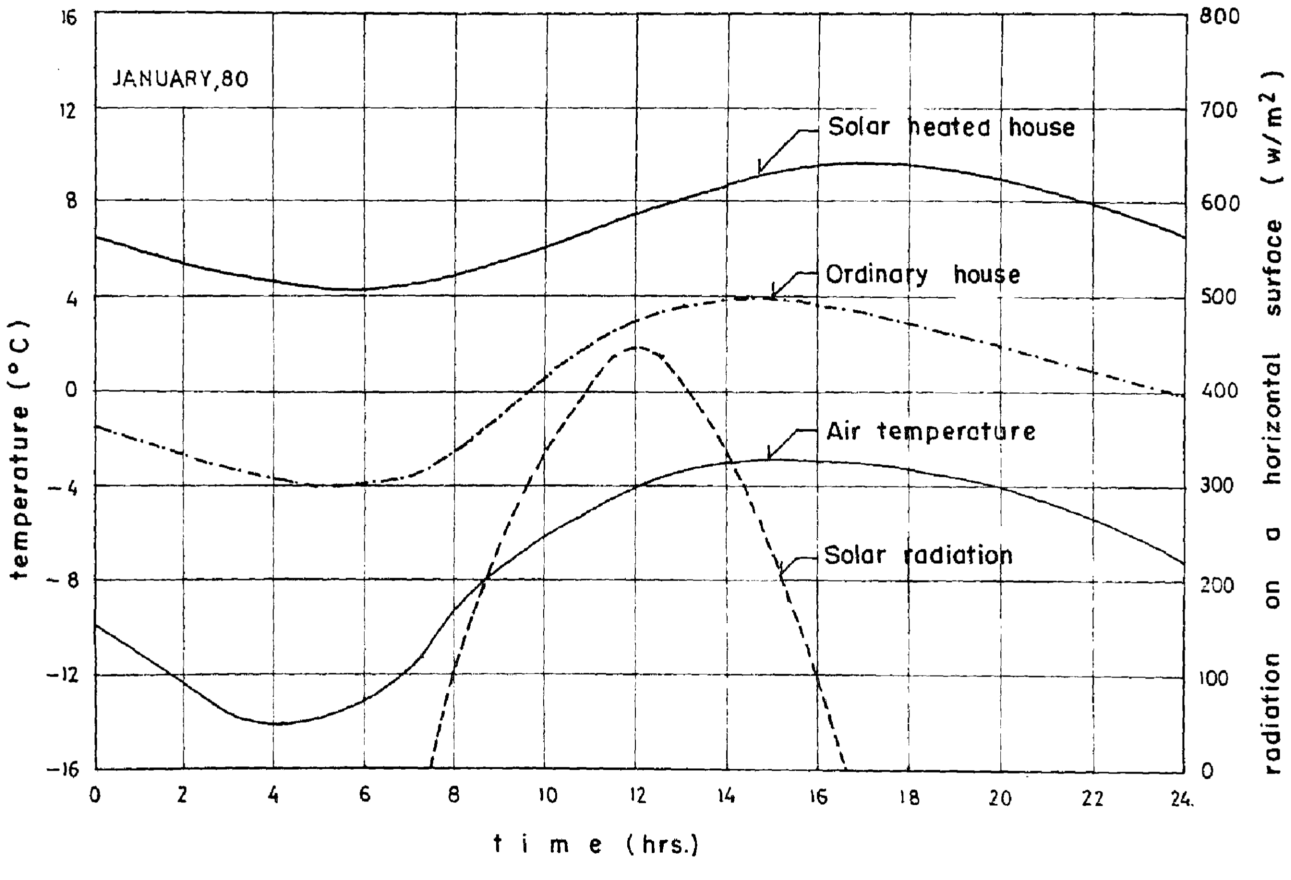


TROMBE' WALL



GREENHOUSE

SOLAR PASSIVE HEATING SYSTEMS
Figure 9



COMPARISON OF DIURNAL TEMPERATURES IN SOLAR HEATED AND ORDINARY HOUSE IN LADAKH (AFTER GUPTA , 1981)

Figure 10

needs to be popularized, and fuel-efficient stoves for cooking and space heating need to be made available to people in the mountains.

Table 1: Estimated Solar Heat Effectiveness and Fuel Savings.

Month	Heating load MJ/Day Normal room	 Solar room	Solar heating fraction	Fuel savings Wood kg/day	 Kerosene liter/day
December	387	129	0.67	38.2	6.68
January	468	159	0.66	55.2	9.70
February	393	141	0.64	44.9	7.84
March	423	141	0.72	41.9	7.18
April	159	54	0.66	08.0	1.39

Area of House = 30 Sq. M.

Reference Temperature of Solar Heating Fraction = 18°C

Gross Heat Value of Fuelwood is 4710 kcal/kg and at 24% Efficiency

Gross Heat Value of Kerosene is 8964 kcal/liter and at 72% Efficiency

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ENERGY TECHNOLOGIES FOR MOUNTAIN DEVELOPMENT

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INTRODUCTION

Material development of services and goods available to mountain populations cannot be conceived of without considerably increasing energy availability. A good correlation is consistently found between energy consumption per capita and standard of living, whether measured across countries or between different regions of one country. It is now recognized that in addition to land, labor, and capital, energy is one of the essential inputs to the economic process.

Mountain populations throughout the world are known for their generally lower standards of living compared to the plains populations of the same countries. Energy required for communications, trade, and transportation, as well as the difficulty of obtaining the excess energy needed for mountain agriculture, all combine to make mountain development a slower and more difficult process than corresponding development in the plains. The impacts of energy technologies on development of mountain populations, with particular reference to health, food, cold stress, and small-scale industries, are described below. Two particular technologies--microhydel and biogas--have not been considered here since they are topics of two separate Chapters.

According to the best estimates, between fifteen and twenty million people live above 10,000 feet in the South American Andes, the Himalaya, and on the Tibetan plateau. Particularly extensive cultural and biological studies[1] have been carried out for two groups among these: Quechua Indians who live on the altiplano in the Nunoa District of south Peru, and the Sherpas who live in the Khumbu region of east Nepal. The Sherpas do not actually live on the Tibetan plateau, but just south of it, in the high-altitude valleys of the Himalaya. Information on the Quechuas mainly comes from the large, well-integrated project initiated, and for the most part led, by Paul Baker of Pennsylvania State University. Information on the Sherpas comes from diverse sources and has not been collected systematically, but complements the data on the Quechuas.

Both the Andean altiplano and the Tibetan plateau are essentially high altitude deserts, consisting of valley floors ranging from 10,000 to 15,000 feet in altitude separated by hills 2000 to 3000 feet higher. Neither area receives much rainfall due to high mountain ranges separating them from the tropical lowlands in their vicinity.

Health

The impact of energy availability on health of mountain populations is most pronounced at high altitudes. The three main forms of stress at high altitudes are restricted food supply, cold stress, and hypoxia. The last refers to decreased availability of oxygen reaching body tissues due to lower density of air at high altitudes. When individuals accustomed to lowland atmosphere travel to high altitudes, they may experience difficulties associated with hypoxia such as dizziness, fatigue, loss of appetite, headaches, and insomnia. For most persons, these symptoms disappear as their hearts, lungs, and circulatory systems adjust to hypoxia. However, adjustment of high-altitude populations to hypoxia is superior, mainly through biological adaptation. Their response to cold stress and restricted food supply is mainly cultural: learned behavior and technology.

In all high-altitude populations, children have been found more susceptible to cold stress due to their large body surface relative to body volume. Neonatal infants are the most susceptible since they are unable to regulate body heat loss by regulation of perspiration or vasoconstriction/dilation. The only way neonatal infants can maintain adequate body temperature is by raising their overall metabolic rate which leads to large energy demands by the body (Weldon and Hill 1983).

Cold stress coupled with hypoxia, resulting from low air densities, leads to high incidence of acute respiratory infection (ARI) in all ages and both sexes. Again, infants are the most susceptible. A survey in Jumla (altitude 7600 feet) revealed a very high incidence of ARI among infants; the total infant mortality was about 490 per 1000 live births, and of these, about 333 were due to ARI (Pandey et al 1983). Such mortality rates are among the world's highest. ARI was found to be the most important cause of mortality and morbidity among infants below one year of age.

Nutrition

High altitude populations also must cope with marginal nutrition. High altitude environments limit the quantity and quality of food crops just as they limit the types of vegetation. The adjustments by the Quechuas for low caloric potential of the environment have been extensively studied by Thomas from the University of Massachusetts, who has identified four specific strategies evolved in the Quechua culture for this purpose (Weitz 1981). First, the Quechuas rely on caloric resources that are well adapted to the environment and produce the most calories for the least amount of work. Second, the surplus resources (mostly animal products) are sold and exchanged for calorically rich products from other areas. Third, children are often assigned active tasks (such as herding) that would be calorically more costly for adults; and fourth, the tasks necessary for sustenance are organized so that large portions of time can be spent in sedentary activities. Even in herding, up to 75 percent of time may be spent in a stationary position.

The potato was originally domesticated in the Andes and has now become the staple food even among the Sherpas, constituting 30 to 44 percent of their adult diet. The rest is made up of cereals and some green vegetables in summer. A considerable amount of local beer made from rice or millet is consumed. About 80 percent of the diet is carbohydrates. In areas well connected to lowlands, such as Leh, an enormous amount of butter is purchased and consumed. About 70 percent of the cash flow at the Government Fair Price shop in Leh reportedly results from sale of various commercial brands of butter, though the shops are stocked with hundreds of other household commodities.

Almost all protein in Sherpa and Quechua diets is vegetable- based. The diets tend to be calorically adequate but deficient in protein. One biological consequence of inadequate caloric or protein intake is growth retardation. Among both Quechuas and Sherpas, physical growth is slower than among lowland populations. Skeletal growth and mineralization are slow; the growth spurt during adolescence is delayed until the early to mid-twenties. Retarded growth or small body size can add up to considerable caloric saving. Thomas has estimated that for the Quechuas, the retarded growth at adolescence alone (between the ages of 15 and 20) saves an average of 121 calories a day or more than 44,000 calories per year (Weitz 1981). This is equivalent to planting an additional 100 m^2 of cropland for each adolescent every year.

There is no consensus yet among experts as to how much of the growth retardation is a response to poor nutrition and how much is attributable to hypoxia; both seem to be implicated. Data from the Andean studies clearly suggests that slow growth is a developmental (not a genetic) response to high altitude conditions. Non-native children who migrate from sea level to high altitudes and remain there while growing up eventually attain the same large lung volume as high altitude natives. Lahiri of the University of Pennsylvania School of Medicine has reported that neonatal infants have the same lung volume at high and low altitudes but a difference appears at adolescence. In addition, he has shown that the high-altitude ventilatory response to hypoxia manifests itself only during adolescence and becomes irreversible by adulthood, again indicating developmental and not genetic adaptation (Weitz 1981).

The impact of altitude on survival begins even before birth. Because of the low amount of oxygen that diffuses across the placental membrane in the foetal system, all foetuses (even at low altitudes) develop in a hypoxic environment. The placentas of Andean women are larger in diameter, thinner, and weigh more relative to foetal weight, than for low-altitude populations. Even then, both fertility and birth weight are lower at high altitudes, both in the Andes and the Himalaya.

Several infectious diseases are not prevalent at high altitudes due to absence of disease vectors. All the same, hypoxia, poor nutrition, cold stress, and respiratory disease combine to significantly reduce survival rates. Only about 65 percent of Sherpas reach adolescence; the rate is roughly similar for the Quechuas. The cultural and biological adjustments cannot completely protect the high-altitude populations from the stress of their environments. The consequence, contrary to the popular assumption of unusual longevity and good health in mountain populations, is lower fertility, prevalence of respiratory diseases, and death at a fairly early age.

Architecture

The annual weather cycle in the high-altitude regions is characterized by comfortable summers and freezing winters. Summer daytime temperatures are about 25°C and winter nighttime temperatures are about -20°C. Large daily temperature swings are common due to thin and extremely dry atmosphere that facilitates radiation loss to the night sky.

Urban houses in Nunoa are constructed of adobe and covered with mud or plaster stucco. Rural houses are made with piled stone walls and thatched roofing. During the cold dry season, nighttime temperatures inside adobe houses average about 7°C. Rural houses offer little resistance to wind and cold, so the temperatures in rural houses fall below freezing during cold winter nights in Nunoa. In Ladakh, temperatures in rural peasant houses have been measured by Paul Mirmont to average about -10°C throughout winter[2].

Sherpa houses are built with thick stone walls that provide good protection from wind, particularly since windows are few and generally only on one side of the house. Most houses have two stories, with the ground floor serving as a manger and a stable. The family lives in one room upstairs, which is so large that much of the benefit resulting from the small heat and moisture gain from the ground floor is lost through the envelope.

In Ladakh, residential buildings are traditionally built two different ways. Ordinary houses are built with sun-dried mud brick walls about one-foot thick, with flat roofs consisting of timber joists supporting closely spaced willow branches which are then covered with about eight inches of mud. The other kind of residential arrangement found in Ladakh is the large monasteries, or *gompas*. These consist of tightly clustered rooms offering relatively small surface area to the exterior. Both the traditional homes as well as the *gompas* have very few windows. In poor peasant houses in the interior of Ladakh, the windows are covered with oiled paper which lets in some light without admitting the freezing wind.

In rural areas (e.g. Zanskar) of Ladakh one also finds a two-storied residential dwelling where the ground floor is a stable and manger for livestock, the second floor is occupied by people for their living activities, and the third level is used for storage of food and hay. Some of the Ladakhi peasant houses are built with mud walls without using prefabricated sun-dried mud bricks. The construction method consists of using woven willow shuttering for supporting the wet mud from both sides. As lower sections of the wall become dry and strong, the willow shuttering is moved up and more mud is added to raise the wall to the desired height.

The current standards for government buildings in Ladakh required by the Public Works Department in Leh are shown below:

Table 1. Specifications for PWD Buildings in Ladakh, 1985

ITEM	SINGLE STOREY	DOUBLE STOREY
Foundation	150 mm concrete then RSM* in mud mortar	150 mm mud mortar over 150 mm concrete
Plinth	RSM in mud mortar with corners in cement mortar	Same as for single story
Super-structure	RSM in mud mortar	or 2nd story must use sun dried brick and mud mortar.
Roofing	Ladakhi type. 100 mm thick mud *phuski* over alkathene sheet over 25 mm wooden planks over timber joists	Same as for single storey
Flooring	40 mm PCC**	
Finishing	Mud plaster both inside and outside the building and whitewash	
Cost/m^2 plinth area	Rs. 1185	Rs. 2260

Note the absence of any required insulation in walls and roof, any requirements for double glazing of windows, or weather stripping.

* RSM - Rubble Stone Masonry
** PCC - Plain Cement Concrete

RELEVANT TECHNOLOGIES

Various renewable energy technologies suitable for high-altitude mountain settlements are described and explained in the sections below.

With intense sunshine available 340 days each year in Ladakh and other high-altitude regions of the Himalaya, solar energy is an effective and inexpensive energy resource. Solar radiation reaches the earth's surface at sea level with an intensity of about 1000 watts/m^2 under a clear sky at noon. At high altitudes, the intensity is somewhat higher since there is less scattering and absorption of solar energy in its passage through the atmosphere. Solar radiation has an equivalent temperature of about 6000°C. This means that it is possible in principle to achieve any temperature up to this maximum by suitably concentrating sunlight. In practice, temperatures much above 1000°C are not practical owing to materials problems. Even below this temperature, the capital costs of capturing solar energy can be quite high. However, the cost of capturing a unit of solar energy rapidly decreases with the temperature at which the energy is needed. The lowest useful temperature for solar energy use is about 30°C, for heating buildings.

Passive Solar Architecture

Traditional Ladakhi buildings have large thermal inertia owing to their massive earth construction. The buildings can be modified to capture solar energy during the daytime and absorb part of the captured energy in the building elements without overheating the building during the day. This heat is released into the building at night. Modifications of the traditional Ladakhi architecture can make use of their naturally high thermal mass. Broadly, design of a solar-heated building follows two strategies: First, the building has to be modified so that it captures solar energy from low-altitude winter sun; and second, the building envelope has to be insulated so that it retains the energy thus captured.

In addition, provision of various heat-rejection methods to avoid overheating, combined with skillful use of thermal mass, keeps the building comfortable all year. Specific approaches for the above two strategies are described below.

Solar energy is suitably captured in a building by either using a *trombe* wall or by Direct Gain design. A *trombe* wall consists of a south-facing wall painted black on the outside with a vertical sheet glass cover on the outside, about 10 cm away. Sunlight shines through the sheet glass on the black wall. Ordinary glass is transparent only to short-wave radiation (visible and infrared components of sunlight) and is opaque to long-wave infrared radiation emitted from the heated black surface. Thus, the black surface cannot easily reradiate its heat to the cold exterior environment. Most of this heat passes by conduction into the wall. If the wall is thermally massive, the heat is stored in the wall and slowly released to the interior of the building. If rapid heat gain to the building interior during daylight hours is desired, the *trombe* wall can be made either of low thermal mass, such as corrugated galvanized iron/asbestos sheets, or can be provided with vents at its top and bottom which allow cool air from the building interior to be sucked into the space between the wall and the glass, heated by the hot black wall surface and returned to the building interior by vents at the top of the wall. Pieces of lightweight plastic film backed with a wire mesh may be installed at the top and bottom vents to ensure that no reverse flow of air takes place during the night through the vents. In the absence of these valves, the warmer air from the building interior is sucked into the *trombe* wall cavity from the top vents at night, cooled by the cold glass sheet, and is returned to the building interior from the bottom vents. The plastic films block this reverse flow since the reverse pressure presses them against the wire mesh, and seals the valve. During forward flow operation, the films gently flap in the jet of air, free from the wire mesh, to allow forward flow of air.

Low mass or vented *trombe* walls are best suited for buildings occupied and used only during the day, such as offices or schools. Unvented high mass *trombe* walls are desirable for buildings occupied at night, such as houses, dormitories, and hotels. The amount of heat captured using vented *trombe* walls can be accurately calculated for a wide range of design parameters (Akbari and Borgers 1979; Borgers and Akbari 1984). The results given in these papers have been subsequently verified with careful experiments conducted independently in Australia and the U.S.A.

Direct Gain design consists of having large areas of south-facing wall made of single or double glazed windows. A large amount of sunlight enters the building interior through the glazing and warms up the building. During the night, occupants move to other parts of the building where heat loss is relatively low. Direct Gain design is attractive where the glare of direct sunlight and possible loss of privacy in part of the building will be acceptable. Another inexpensive solution for solar heating of buildings is attaching a sun-space to the building. The sun-space is a south projecting part of the building that is enclosed on four sides (east, west, south, and top) with glass. Air from the heated sun-space can be convectively moved to cooler parts of the building to warm them.

Insulation in the building envelope prevents loss of heat from the building to the environment. In fact, insulating and weather stripping are the two most effective measures to keep buildings warm in winter. These should be implemented before attempting any scheme to capture solar energy for space heating; all the exterior surfaces of the building should be insulated. This can usually be done without modifying the traditional architectural style, and without use of expensive material.

An attractive solution demonstrated in Leh by C. L. Gupta (1981), Helena Norberg-Hodge (1979), and by Paul Mirmont is to build double-walled building envelopes with space between the two wall layers packed with straw. The roof is also insulated with 20 cm straw added between the willow branches and the top mud layer. This improves the insulation value of the walls from the traditional value of $0.7 m^2$-°C/watt to $3.2 m^2$-°C/watt. In addition, if the ordinary wooden plank door is replaced with a sandwich panel door containing 5 cm thick rigid polystyrene foam, the resistance to heat loss of the entire envelope can be further increased by a factor of 2.5.

Subsequent improvements in the thermal integrity of the buildings would consist of changing windows from single pane to double pane and decreasing the subsequent improvements in the thermal integrity infiltration of outside cold air into the building with weather stripping. A fairly comprehensive reference for solar heating of buildings is found in Mazria's book (Mazria 1979).

Solar Hot Water

In Tibet as well as in Ladakh, water scarcity is a problem due to inadequate precipitation. In Leh, water is available to city residents in winter at only four public water taps. Hot water is a luxury due to the high cost of fuel. A majority of the population reportedly go without a bath for several months at a stretch. It is relatively inexpensive to provide hot water with the use of solar energy. Batch-type solar water heaters can be fabricated costing no more than Rs. 1400 per unit to yield 40 liters of hot water each day. One such design by TERI is being tested in Leh. At lower altitudes, relatively warmer winters mean even lower costs for solar water heating.

Solar Energy for Food Preservation and Production

Despite harsh weather, a few fruit orchards are cultivated near the Indus River, where water is available. Peaches and apples grown locally are available only for immediate local consumption. It is possible to use solar energy for operating agricultural dryers so that food products can be stored beyond the harvesting season. Several designs can be found in the survey by Lawand (Lawand 1975).

In the course of one poultry research project conducted among the Quechuas in Peru, the reason for the low rate of weight gain by young chicks at that altitude was identified to be the low ambient temperatures particularly during the cold nights. A solar-heated chicken brooder using exclusively local skills and materials was developed and successfully field-tested. (Benard et al 1981). The brooder consists of a sun-space which receives considerable solar energy during the day. Heat from the sun-space is absorbed in an inexpensive, phase-change, thermal storage unit during the day. The chicks stay away from this hot part of the brooder during the day and spend most of their time in a shaded area; during the cold night, they huddle close to the thermal storage unit. The design is adaptable to any sunny cold climate, typical of high-altitude mountain regions.

Solar-Assisted Biogas

It is known that gas yield from biogas digesters decreases by a factor of approximately two for every 10°C drop in the digester temperature. In China, biogas digesters effectively shut down during the sub-zero winter. It is possible to warm small quantities of water inexpensively in shallow solar ponds. This warm water when used to make the slurry for the biogas digester raises the temperature of the digester and consequently its gas output considerably. V. V. N. Kishore of TERI has been experimenting with this technique for biogas digesters of Chinese design (known as Janata design in India) and these will be tried in Haryana and Jammu. N. K. Bansal of the Indian Institute of Technology, New Delhi, has been conducting experiments with KVIC design biogas plants which consist of enclosing the entire dome in a transparent plastic shell, effectively forming a sun-space around the biogas digester. These technologies are not suitable for extremely cold climates of high-altitude regions such as Ladakh and Tibet; they will be useful in lower altitude mountain regions.

Improved Space Heating and Cookstoves

During winter, it is common to use hard coke-fired space heaters in Ladakh, at least among those who can afford fuel. Since hard coke costs are high, use of this space heater (*bukhari*) translates into a fuel cost of Rs. 3 per hour. The *bukharis* have not been designed using modern engineering knowledge and probably their efficiency can be improved by 50 to 100 percent with only a marginal increase in cost. TERI is presently developing more efficient *bukhari* designs.

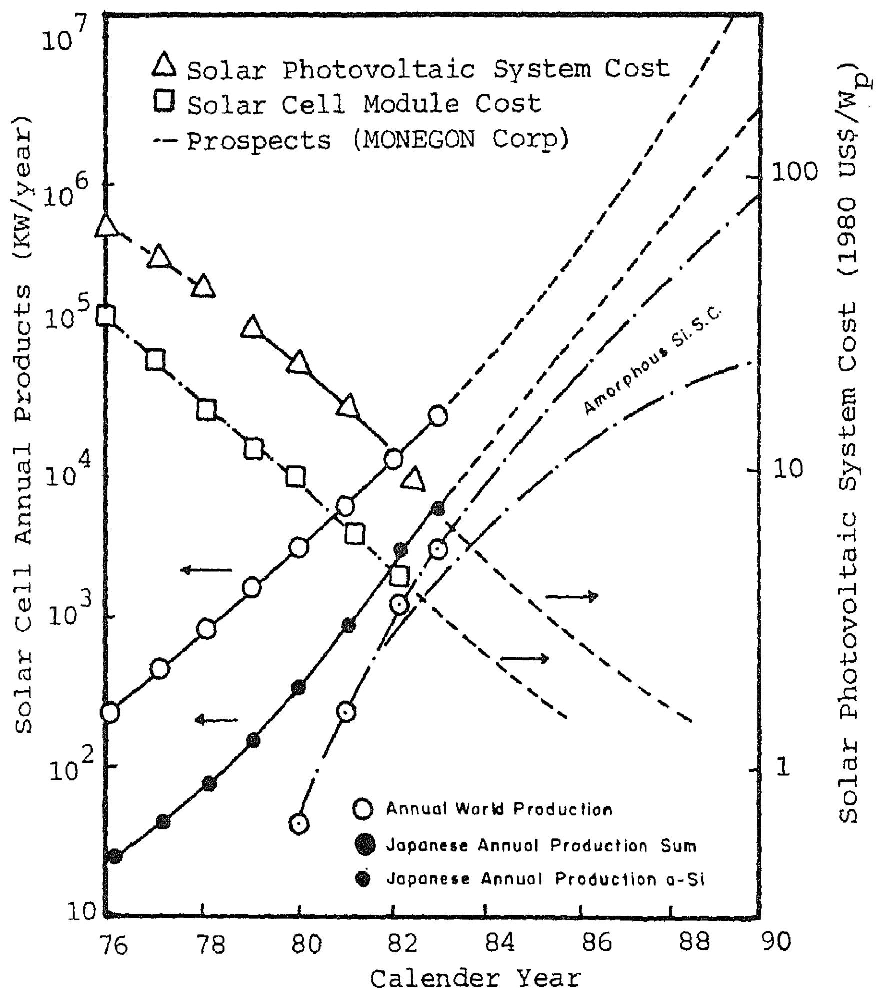
Cookstoves made from oil drums have recently become popular in Ladakh. They have extremely elaborate and ornamental designs and cost up to Rs. 6000. Their energy efficiency, however, has not even been tested. Preliminary inspection leads one to suspect low efficiency (about 10 percent). It seems likely that it could be improved significantly with a little effort.

Photovoltaics

There exist several techniques for direct conversion of sunlight into electricity. The most successful of these is the silicon solar cell. Other technologies (e.g. Gallium Arsenide, Photoelectrochemical cells, etc.) are not yet mature enough for practical field applications. A silicon solar cell essentially consists of a wafer of pure silicon which has been purposefully doped to alter its electronic characteristics.

Silicon photovoltaic cells were first commercially developed and used for space applications. At that time, they were extremely expensive and thus could only be used for supplying electrical power to satellites and spacecraft. The prices of photovoltaic cells have declined sharply since 1970 as a result of concentrated efforts in this direction undertaken mostly in the U.S.A. Photovoltaic modules are rated in terms of maximum power they produce when exposed to solar radiation that has passed through one standard atmosphere of air. (Since passage through the atmosphere attenuates sunlight, the solar spectrum is characterized as AM 1, AM 1.5, AM 2, etc., giving equivalent air mass through which sunlight may pass before it reaches the observer.) The common way of rating photovoltaic modules and cells is in terms of Watts-peak (Wp). A cell rated at 1 Wp would thus produce one watt of power when exposed to AM 1 radiation incident normal on its surface. In 1970, photovoltaic modules cost US$ 150/Wp. This cost rapidly came down to US$ 50/Wp in 1976 and afterwards has shown an equally dramatic and rapid decline. Annual photovoltaic production measured in terms of kW/year has shown an exponential increase since the early 1970s. In 1976, the production was about 300 kW/year and in 1984 it was about 30,000 kW/year. More details are shown in Figure 1 (Hamakawa 1985).

Of course a photovoltaic cell, module, or system rated at a given power does



Growth of world and domestic annual production of solar cell modules and transitions of module cost and system cost.

Figure 1

not produce that power 24 hours a day. It does not even produce that much power during the daylight hours since the energy incident on the panel is a function of length of the atmosphere through which the sunlight is attenuated and decrease in radiation flux due to non-normal angles of incidence.

An important advance in further decreasing the cost of silicon photovoltaic modules has been the maturing of technology for amorphous silicon (a-Si) PV cells. Amorphous Silicon has a coefficient of photon absorption about 40 times larger than crystalline silicon. This allows for amorphous silicon cells to be extremely thin. (The optimal thickness for crystalline silicon cells is 70 um. In practice, the cells are about 300 um thick for mechanical strength. In contrast, a-Si cells have a thickness of 0.5 um.) There are about 60 percent losses involved in preparing silicon wafers from cylindrical ingots of pure silicon. Though these can be considerably reduced by producing silicon ribbons directly from molten silicon using the Edge Defined Growth technique, polycrystalline silicon cells still need 600 times more pure silicon than amorphous silicon cells of the same area.

The amorphous silicon cells are prepared by directly depositing a very thin film of a-Si on a metal substrate. In 1985, Sanyo Electric Company of Japan announced that they had made a-Si cells with the conversion efficiencies shown in Table 2.

Table 2. Conversion Efficiency of a-Si Cells

AREA	CONVERSION EFFICIENCY
1 cm^2	11%
100 cm^2	9%
600 cm^2	7%

Sanyo has developed a microfabrication technology for producing a-Si solar cells that is completely automated and uses laser-scribers for evaporating sublayers of an a-Si cell assembly. This is a completely dry process and is expected to operate continuously.

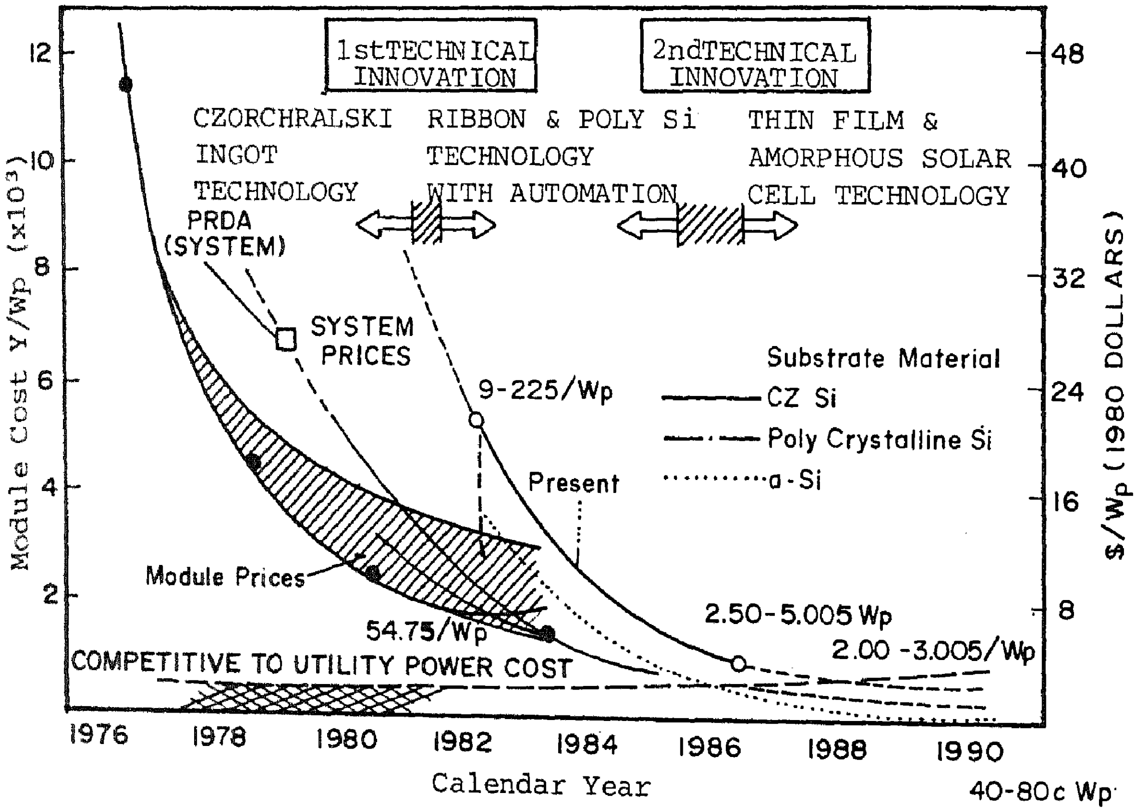
Amorphous-Silicon cells have so far had relatively low efficiencies (about 6 percent) of photovoltaic conversion compared to polycrystalline a-Si cells (typically 12 percent or more). Various innovations have successfully pushed the efficiencies up as indicated in the above table. A-Si cells also have tended to deteriorate rather rapidly when exposed to direct sunlight. Thus the applications of a-Si cells have almost extensively been in desktop calculators (these calculators, though called "solar calculators", will not last long if operated in direct sunlight). Japanese researchers were able to stabilize a-Si with respect to exposure to direct sunlight only in 1985. Toyota has announced that its best line of cars will have their tops coated with a-Si cells which will power the instrumentation, charge the battery, etc. Sanyo has also produced experimental a-Si roof tiles and tiles for exterior walls of buildings, which could power all the appliances inside the building. These recent advances indicate that a-Si technology is likely to completely overtake polycrystalline ribbon technology in the near future. The cost transition of solar cell modules and of photovoltaic systems with various technological innovations is shown in Figure 2, also from Hamakawa (Hamakawa 1985). The estimated point of transition where photovoltaic power system costs, would favorably compare with utility (thermal) power costs is expected to be between 1986 and 1989.

A considerable amount of high-temperature processing is needed to obtain ultra-pure silicon which leads to such a large consumption of energy in the production of crystalline silicon cells that the payback period for the energy invested in the production is about 10 years, assuming continuous daily operation of the cell. Since 10 years is approximately the lifetime of the photovoltaic system, it does not seem attractive to invest energy in photovoltaic systems. A-Si cells, however, use 600 times less silicon per unit area and hence, despite their slightly lower efficiency, energy payback periods for a-Si cells are about one year.

In remote mountain areas, the cost of transmission and distribution of power can be very significant. A transmission and distribution network is a fixed cost that depends more on the distance from the grid line and less on the total energy demand for small load centers. Photovoltaic system costs are, on the other hand, directly proportional to the energy demand, and more or less independent of location. A study done at TERI indicates that state-of-the-art photovoltaic power systems become cost-effective compared to grid-connected electric power supply for electrification of small mountain villages (peak load 40 kW; daily energy demand 500 kWh) located more than 10 km from the existing grid lines. These conditions are satisfied for the majority of unelectrified mountain villages. For villages with less demand, photovoltaics are cost-effective even at distances less than 10 km from the grid lines. For larger villages and towns where the electricity demand is higher, grid-connected power systems remain cheaper than photovoltaics for distances greater than 10 km from existing grid lines.

Electricity Production and End-Use Efficiency

For various demographic and topographic reasons, the transmission and distribution of electricity is expensive in mountain regions. With the sharply declining prices of photovoltaic systems, their use has already become cost effective in remote villages. Electricity produced with hydropower can be inexpensive in principle. However, persistent cost and time overuns make hydroelectric power sometimes enormously expensive. The four MW minihydel projects on the Indus River at Stakhna near Leh will cost about Rs. 120 million. The cost thus translates to Rs. 30 per watt of installed capacity. The dam, however, will produce 4 MW of power only during summer. During the sub-zero winters, the flow in the Indus river decreases



Cost transition of solar cell modules and photovoltaic systems with prospective technological innovations.

Figure 2

considerably and the power output is expected to drop to only 2 MW. Thus the cost for annual average capacity is Rs. 40 per Watt installed. This is comparable to the costs expected for large photovoltaic installation before the end of this decade.

The alternative for hydroelectricity is generation with diesel engines. Efficiency of diesel generation decreases by three percent with every 1000 feet increase in elevation. The diesel generators in the 1 MW power house near Leh operate at best at 70 percent of their rated capacity. The cost of transporting diesel to high altitudes is also significant, as is the cost of transmission of distribution network over rugged terrain. The Power Development Department of Jammu and Kashmir State has estimated that the cost of electrical energy from its diesel generating stations for Leh was Rs. 4.10/kWh in 1982-83. The cost of electricity supplied to remote areas like Zanskar was much higher: Rs. 10/kWh. The diesel has to be trucked to Leh and stored in underground reservoirs for the winter since the road to Srinagar is snowbound and closed by mid-November. End-use efficiency of electricity thus becomes extremely important, not only to the residents of Leh (for whom the billing rate is about Rs. 0.65/kWh) but to the utility which bears the cost of subsidy. All electric-resistance heating is forbidden in Leh (except at hospitals for sterilization, etc.). Since the electricity is available only for five evening hours, almost all consumption is confined to lighting.

The demand has grown faster than the generation capacity and the supply voltage is usually in the range of 140 to 180 volts. This low voltage makes it impossible to use fluorescent lamps which normally are five times more energy-efficient than incandescent lamps. If everyone switched to fluorescent lamps there would be a 2.5-fold drop in electricity consumption and a twofold increase in the light produced. However, there are obvious management and organizational problems which must be overcome in implementing such a massive switch.

Waste-Heat Recovery

Diesel generation also produces twice as much heat as electricity. This heat is presently all dumped into the atmosphere. Several companies in India manufacture equipment to capture waste heat from diesel electric generators with ratings larger than about 500 kW and make it available for various low temperature applications (temperatures of less than 120°C). The amount of waste heat thus recovered is equal to about 60 percent of the electrical energy being produced. No such equipment is presently in use in Ladakh to the author's knowledge. It is economically attractive to capture this free heat, and use it for process industries such as food preservation or canning, which would give rise to local employment and income generation.

Wind Power

Winds flowing over mountainous terrains are strongly influenced by the terrain geometry, and it is commonly possible to identify passes and channels where the wind is funneled naturally. Wind power is thus highly site-dependent. Detailed monitoring of local wind characteristics is essential for identifying sites for wind power generation, or before writing off any mountain district as having no potential for wind power generation. The wind power potential in the Indian Himalaya remains almost totally uncharted at present. The lowest cost per unit of installed capacity for wind machines is rated at about 50 kW with a diameter of about 15 meters. This is somewhat different from the initial expectation of about 10 years ago that economies of scale would continue to make wind power cheaper as the rated power of the wind machines increased. It is fully expected that with better understanding of the low - velocity, high - turbulence aerodynamics, and with the development of better fatigue-resistant materials for wind turbine blades, the lowest wind turbine cost (per kW of rated capacity) would gradually shift to larger wind turbines in the rotor diameter range of 20-30 meters.

A wind farm of 50 kW-rated wind turbines with a total installed capacity of 6 MW would currently cost about Rs. 120 million. Fairly attractive terms of payment are available from manufacturers for installing such wind farms where only 25 percent of the payment is to be made on installation with the rest of the amount to be paid over the next seven years. The annual payments are tied to the actual annual energy output from the wind turbines. If the wind turbines produce less energy in a given year for any reason, the owner pays a proportionately smaller amount to the installers, the difference being made up by an insurance company.

The U.S.A., West Germany, and Sweden have developed large wind turbines rated at 2 to 3 MW over the last 10 years. Both the West German and the U.S. programs have presently been closed down due to technical difficulties, or lack of funds. The Swedish research program with two large wind turbines at Nasudden and Maglarp continues to operate.

Underground Refrigerated Storage

In most high-altitude regions, electric power is not available continuously and often is not available at all. This leads to problems in keeping a supply of refrigerated vaccine on hand in hospitals and for public heating purposes. Inexpensive refrigeration, if available at these locations, can also be used for storage of vegetables and other food products. The extreme cold of the high-altitude winter season and the large thermal mass of soil can be used to design underground low-temperature storage facilities which do not use any electricity. In Ladakh, TERI is designing a low-temperature storage facility for the Leh District Hospital where vaccine would be stored approximately 10 meters under the soil surface. Detailed numerical simulations of heat conduction in the soil indicate that at these depths the annual temperature swing is from +8 to -8°+C, which makes the facility suitable for storage of BCG/Typhoid and DPT/DT/TT vaccines. (If these vaccines freeze, their proteins are denatured and the vaccines have no medical effectiveness after thawing. Storing them above ground in winter quickly leads to their getting frozen solid and renders them useless.) Underground storage facilities due to the large thermal mass of soil between the storage area and the ground surface, provides a more or less uniform storage temperature year-round that protects the vaccines.

Vegetables are traditionally stored in Ladakh in pits six feet deep, and covered with about a foot of soil. The vegetables stay fresh for several months and do not spoil due to freezing or overheating. The Council for Administration and Rural Technology (CART) of the Government of India is presently interested in developing scientifically designed underground vegetable storage units for Ladakh based on the above principle.

Both the technologies described above use the natural swings in ambient temperature to provide low temperature storage facilities, whereas other alternatives would need a considerable amount of electric power and fairly sophisticated control equipment. At lower altitudes in the mountain areas (e.g. Srinagar) sometimes the summer temperatures are sufficiently high that air-conditioning is required in critical areas (operation theatres, satellite communication facilities, computer centers, etc.). It has been demonstrated that in this case also it is not only technically feasible but also economically cost-effective to capture the sub-zero cold of the winter months to freeze a large mass of wet soil underground. During the summer months when cool air is needed for air-conditioning, this frozen mass of soil can be used to absorb the indoor heat in place of relatively costlier electric air-conditioning (Francis 1985).

RESEARCH AND DEVELOPMENT NEEDS

Paucity of data is the first difficulty faced by any research or development program on renewable energy in the mountain regions. Renewable energy potential is a highly site-specific variable. The India Meteorological Service already has several weather stations throughout India which record hourly solar radiation, temperature, wind speed, relative humidity, etc. There are very few stations of this kind in the mountain areas. In Ladakh, there is only one station and that data is normally available only to the Indian Air Force. A series of such weather stations need to be scattered throughout the mountain regions to enable planning for exploitation of renewable energy potential.

The technology of passive solar heating of buildings is now well understood and there exists a large body of practical experience in Europe and North America on this subject. This information is all in the public domain and several books and research papers have already been published on this topic. It is important that this knowledge be transferred to the mountain population. Most of the mountain population is poor and their dwellings are not designed and built by construction professionals such as architects, engineers, and building contractors. These ordinary people have to be provided with guidelines in their local languages which will explain in simple terms how new dwellings can be constructed or their existing houses modified to capture and retain solar heat. Demonstration buildings also have to be erected which will prove the concepts to the local population.

The CEC (Committee of European Communities) has presently funded a small project in Ladakh with Paul Mirmont,[3] which has constructed 15 passive solar houses in villages surrounding Leh. The incremental costs for these houses, (over the cost of the standard design) is only Rs. 5000. The CEC project also envisages printing of manuals in Ladakhi and Tibetan languages which will explain the passive solar design concepts in simple terms. This work needs to be expanded considerably throughout Ladakh and other high-altitude mountain regions. It would be essential to create a resource center (a kind of energy extension service) which would provide advice and plans for solar building. Since cold stress is one of the three main health problems facing high-altitude mountain populations, efforts to introduce passive solar architecture on a wide scale will surely have a significant impact on health and survival. Government Public Works Department specifications for buildings should be modified to specify levels of insulation, window areas, and double glazing on windows as well as weather stripping as part of government building requirements.

Due to high costs of fuelwood, coal, kerosene, and diesel, solar hot water is probably already cost-effective in most high-altitude mountain regions. Without detailed radiation and weather data, it is difficult to quantify the cost of solar hot water at any specific site. However, it is likely that solar hot water would not only be cost-effective due to extremely clear skies for most of the year, but its use would be very desirable since a large part of the population reportedly goes without bathing throughout winter.

Solar chicken brooders and greenhouses for extending the vegetable growing season beyond summer need to be experimented with and disseminated widely. Experiments with subsoil drip irrigation and horticulture under controlled atmosphere (under polythene sheets) to prevent excessive water loss also need to be investigated.

In low-altitude mountain regions, biogas digesters almost stop producing methane in winter. Solar energy can be used either via shallow solar ponds or with sun-space enclosures to keep the biogas plant functioning throughout winter. More research needs to be conducted on both these methods and results disseminated.

Photovoltaics are already cost-effective in most of the mountain region since the cost of transmission and distribution networks is extremely high. The existing photovoltaic panels made in India have low efficiency and a short life (about two years in Ladakh) and thus are not cost-effective. The quality of indigenously produced panels has to be improved to international standards so that this technology can be used widely.

Most of the electricity produced in the high-altitude mountain regions is developed from diesel engines. It is very inexpensive and cost-effective to capture a part of the heat exhausted by these engines and use it for various intermediate temperatures (80°-130°C) applications. Several companies in India already manufacture equipment to capture part of this heat equal to about 60 percent of the electrical output for diesel gensets rated larger than 500 kW. This technology needs to be disseminated widely, and also heat recovery units for smaller rated diesel gensets need development.

The end-use efficiency of electric appliances in high-altitude mountain regions becomes particularly important since the cost of electricity is very high. In mountain areas where electricity is used mostly for illumination purposes, a switch from incandescent lamps to fluorescent lamps seems economically attractive even if it involves investments in voltage stabilizers to ensure a reasonably high voltage supply to the fluorescent lamps.

Traditional domestic appliances using fossil and wood fuel such as *bukharis* and *chulhas* are generally quite inefficient and can probably be significantly improved with little effort. Introduction of pressure cookers throughout high mountain areas seems desirable both from the point of view of improved energy efficiency as well as forest conservation.

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POTENTIAL FOR SMALL, MINI AND MICROHYDEL PROJECTS IN THE INDIAN HIMALAYA

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INTRODUCTION

Generation of power in India from small hydroelectric units dates back to the late nineteenth century. The first 130 kW hydroelectric generator was set up in Darjeeling in 1897. Two 100 kW units were set up in Simla in 1908, followed by three units of 250 kW and two units of 500 kW in Chaba (60 km from Simla) between 1912 and 1918. These efforts to develop hydroelectric generation were to meet the requirements of the British government which had its summer capital in Simla. Darjeeling, famous for its tea estates, also was a popular summer resort in the eastern region. The hydel units in Sivasamudram were commissioned to meet the power requirement for the Kolar gold fields. When the British left India, total installed capacity was about 2300 MW, of which nearly 40 MW of power was generated by small, mini, and microhydel, mainly in the hill regions.

Today, the total installed capacity in India is about 44,000 MW, a 19-fold increase in 38 years. Small hydel power generation in the mountain regions has increased only about three times during this period and is still a meagre 117 MW.

Little was done during the fifties or the sixties to electrify the hill regions. It was in 1974 that the government of India set up a committee to investigate rural electrification. This committee strongly recommended that intensive efforts be made for setting up microhydel units, particularly in the north-eastern region. Thus, Arunachal Pradesh has come to have a number of microhydel units during the past decade. The impact of electrification on that region is discussed in the latter part of this paper.

Recent worldwide efforts to harness renewable energy sources and the warnings of ecologists about the threats of large-scale hydroelectric systems have turned attention to an age-old method of generating power: using small, mini, and microhydel units. Small hydropower generation has begun to receive official attention.

To follow the definition of the Central Electricity Authority (CEA) of India, the classification of small, mini, and microhydel plants is as follows:

- Small hydel project: 2001 kW - 15000 kW and no individual units ratedmore than 5000 kW
- Minihydel project: 101 kW - 2000 kW each unit usually less than 1000 kW
- Microhydel project: Up to 100 kW

(For the sake of convenience all these categories have been occasionally referred to as SHP in this paper).

All these hydel schemes can again be categorized into:

- High head schemes > 50 meters
- Medium head schemes 20-50 meters
- Low head schemes < 20 meters

The first two categories particularly are of interest. Small hydel units, usually installed at canals, operate at low head drops. These are primarily in the plains (Map 1) and will not be discussed in detail in this paper.

THE PRESENT STATUS AND FUTURE POTENTIAL OF SMALL, MINI, AND MICROHYDEL UNITS IN INDIA

The growth of SHP in India has been extremely poor. The total number of plants in operation in India is 84, generating about 168 MW.

- In India, SHP constitutes about 1.2 percent of total hydropower and 0.38 percent of the total installed capacity:

- Out of the 84 SHP **in operation in** India, 20 small hydel units generate 129.3 MW (77 percent), 51 minihydel units generate 37.9 MW (22.5 percent), and 13 microhydel units generate 0.675 MW (0.5 percent).

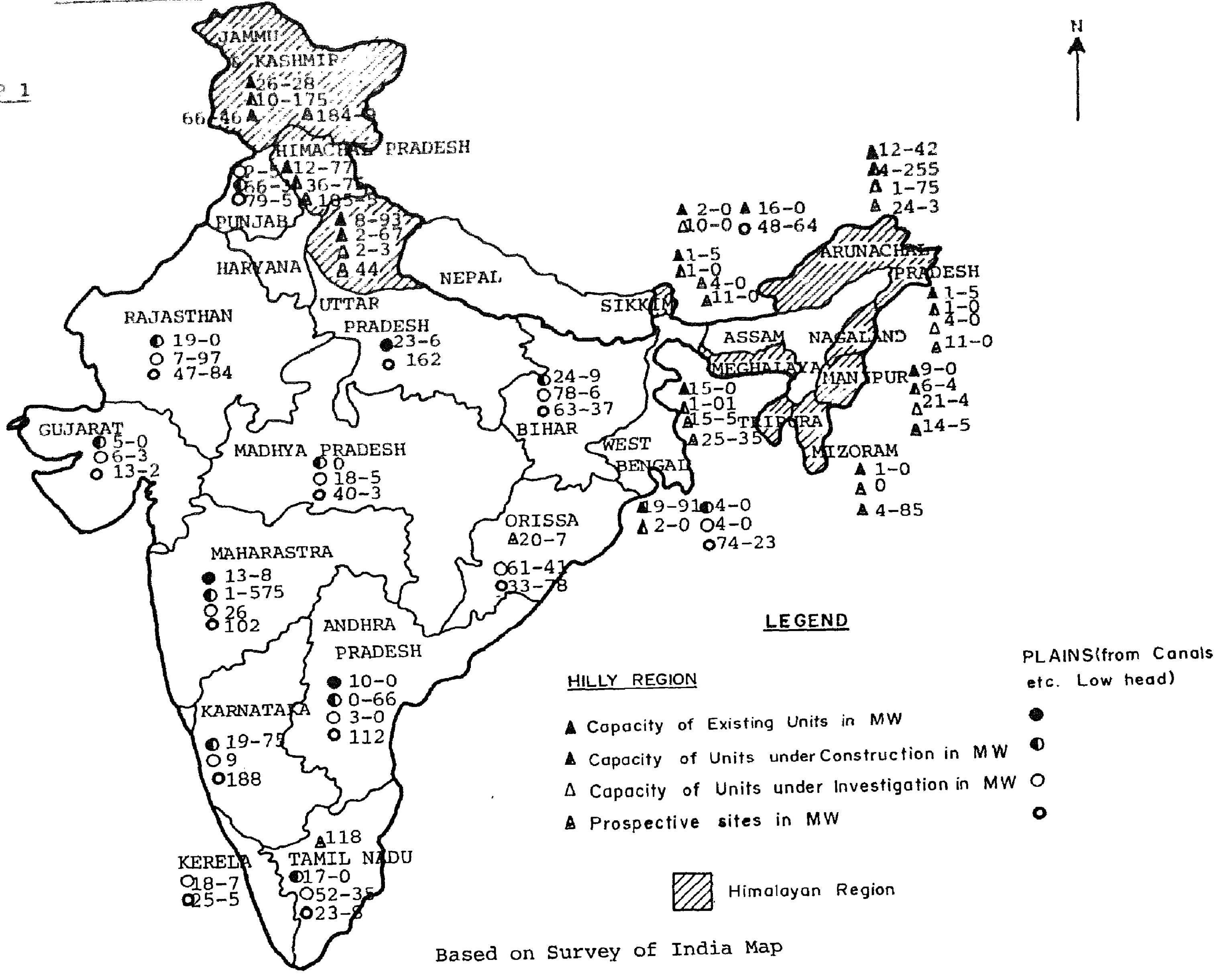
- Out of the 71 SHP **under construction** in India, 18 small hydel units will generate 125.65 MW (78.78 percent), 39 minihydel units will generate 33.0 MW (20.7 percent), and 14 microhydel units will generate 0.8 MW (0.52 percent).

It is interesting to note that the relative emphasis on small, mini, and microhydel units has not altered much over the years. For one small hydel unit, India has four mini or micro units in operation.

The following section provides information about the SHP in operation in India (Map 1) and a summary of the potential explored so far[1].

MAP 1

EXISTING AND POTENTIAL SMALL/MINI/MICRO HYDEL CAPACITY IN INDIA



Based on Survey of India Map

Table 1: SHP in Operation, under Construction and Investigation

	In hill regions		In the plains	
	No. of sites	Installed capacity in MW	No. of sites	Installed capacity in MW
SHP in operation	72	116.7	12	51.3
SHP under construction	50	67.76	21	90.4
Projects under investigation (CEA)	55	130.4	143	358.6
*Prospective sites (REC)	250	660	810	1068

* Approximate figures REC - Rural Electrification Corporation

Of the figures in the hill regions, nearly 450 sites have been identified, and these will provide about 660 MW at high head. These sites are not all in the Indian Himalaya region.

It may not be possible to install SHP in all the prospective sites listed by the REC. On the other hand, this list is not necessarily exhaustive. It is likely that India's SHP potential is significantly more than the 1800 MW indicated in Map 1. A figure of 5000 to 6000 MW has been suggested (Newsletter of the Asia Pacific Regional Network for Small Hydro Power 1985). The potential in the Himalaya region is likely to be correspondingly high.

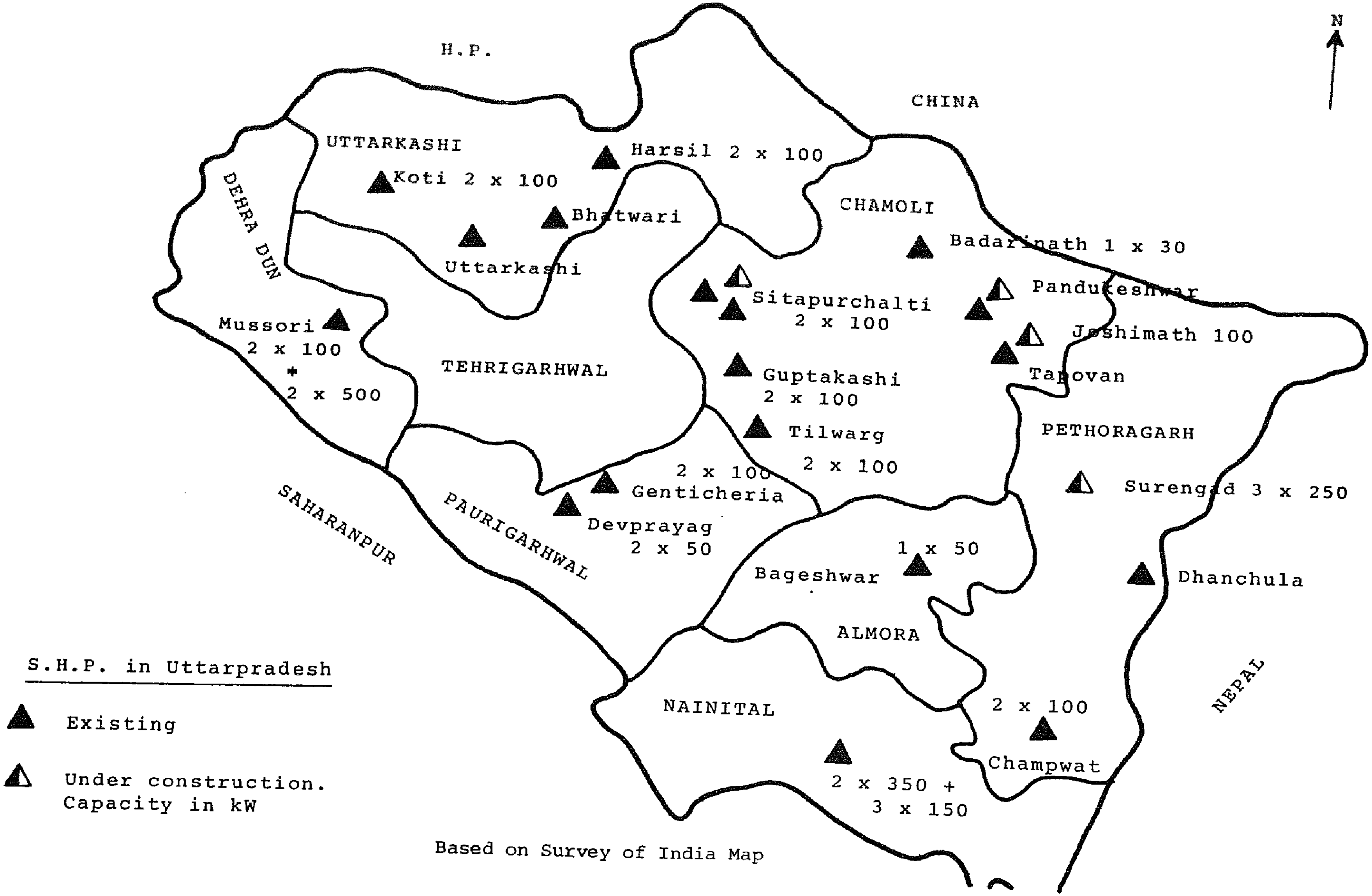
The states that contain parts of the Indian Himalaya are Jammu and Kashmir (J and K), Himachal Pradesh (HP), Uttar Pradesh, Sikkim, Arunachal Pradesh, Nagaland, and Manipur (shaded in Map 1 ; Meghalaya, Mizoram, and Tripura may also be included. Map 2 gives a typical distribution of SHP in northern Uttar Pradesh as well. The potential and feasibility of SHP in these areas need to be studied.

TECHNOLOGY OF MINI AND MICROHYDEL UNITS

A brief outline of the SHP technology, obviously not intended for experts in this field, follows.

Small hydrogeneration at canal drops or low dams falls into the low head range (i.e. 20 meters or less). In this paper, however, we shall concentrate on the medium and high head types which are more prevalent in the Himalaya region. Figure 1 represents a typical mini or microhydel system which consists of a diversion weir, an intake structure, a desilting chamber, a penstock or other conveyance facility, a power house, hydro-generating equipment, a transmission line, and an access road.

MAP 2



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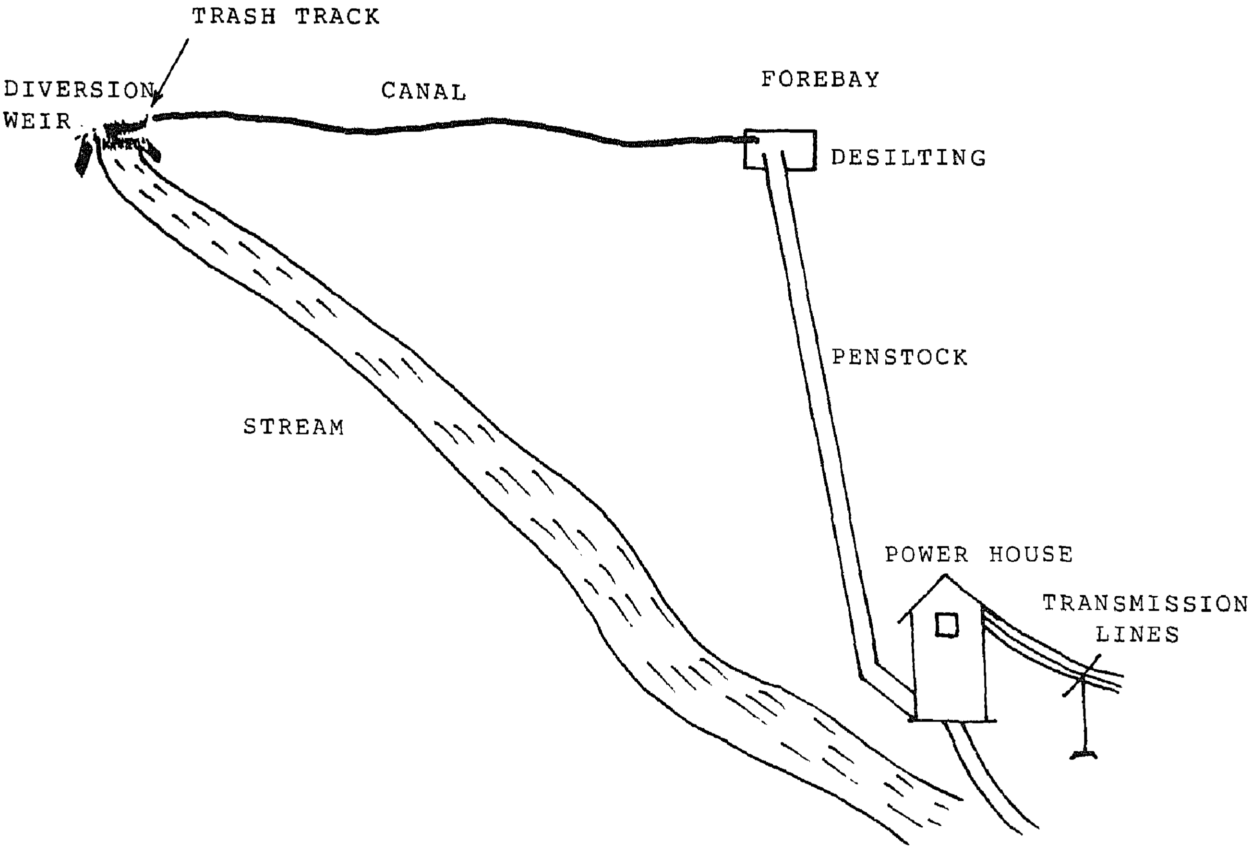


Figure 1. A Typical Mini/Micro Hydel Run of the River Scheme

A **diversion weir** diverts water out of the stream into a channel or directly into a penstock via an **offtake structure** which incorporates a **trashtrack** to exclude floating debris and the larger sediment. The diversion weir may be of two types: boulder structure which is a trapezoidal structure of boulders or rubble masonry section one or two meters high with a slanting upstream face, or a trench-type weir which is particularly suitable where boulder structures are vulnerable to damage from other boulders. It is a simple trapezoidal trough made of masonry or concrete covered with a trashtrack over the full width of the stream. One of the major requirements in mini and microhydel projects in the Himalaya region is a desilting chamber. Generally hill streams carry appreciable silt and sand during rainy seasons causing considerable damage to the turbine runner. The **conveyance facility** transports the water from the diversion weir area to the power house and can be a **penstock** or a combination of **canal** and penstock. A canal (or a channel as it is often called) combined with a penstock is more commonly used. The gradient of the channel is kept low (about 1:750, for example). The stream has a higher gradient (typically above 1 in 40). Water diverted from the stream flows down the channel a distance of 2 to 3 km and develops a head of about 50 to 75 meters (Figure 2). The canal ends in a **forebay** from which a penstock then carries this water to the power house.

If the bed slope of the stream is steep (for example one in ten) it will be cheaper and faster to adopt a direct penstock for conveyance of the water.

The **power house** shelters the turbine-generating equipment and controller and is designed according to local practice. The selection of the turbine/generating equipment depends on the flow, hydraulic head, and other factors.

For the higher heads, usually with a diversion-type project, the turbines are often the impulse or Francis type. Where long penstocks are involved, the impulse-type unit is usually preferred since water-hammer stresses are minimized. This is due to the use of jet deflectors and the slower allowance valve closing times when outages occur and rapid shutdowns are necessary. Impulse units also suffer less damage from sediment than do Francis units.

As far as the choice of generators is concerned, it depends very much on the power market a SHP has to serve. The SHP may serve an isolated site, as is frequently the case in the Himalaya region, or it may serve a power market which is located so that the hydropower may be fed into the main grid.

In case the power market is an isolated site, the more expensive *synchronous generators* are used. For grid ties, induction generators (Allan 1960) are recommended because they are cheap and rugged, and need less control.

For mini and microhydel units, power is generated at 440 V, and a transformer is not required unless power is to be transmitted to a distance greater than 5 km. For minihydel units it is not uncommon to have two, three or four turbines or generators for operating from a common header fed by the penstock. Hydroelectrical power can be computed by a very simple formula:

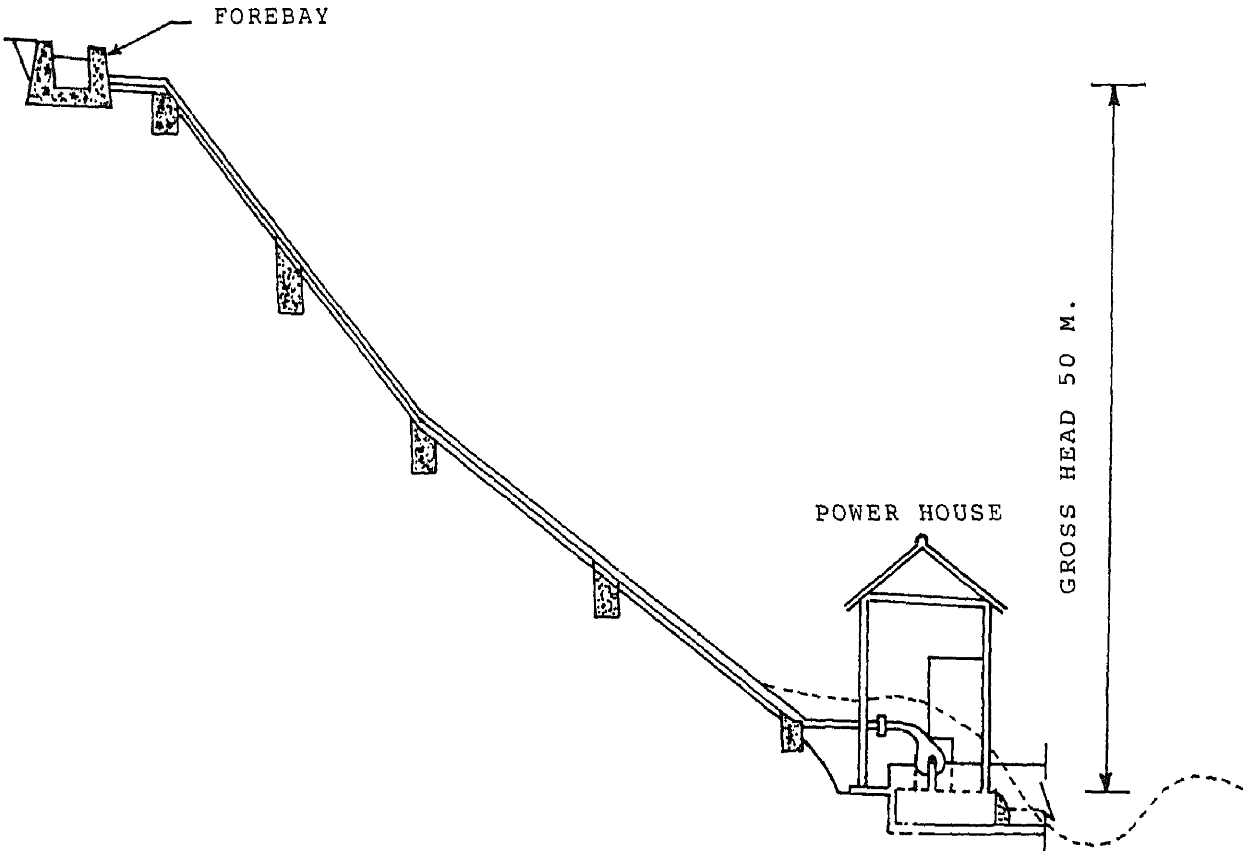


Figure 2. SECTION OF PENSTOCK

$P = 9.81Q.H.e$

where P = power in kW

Q = flow in cubic meters per sec (cms)

H = head in meters

e = turbine/generator efficiency

A 20 kW microhydel unit that was set up in Karnataka for H=70 m, Q=0.07 cms (70 liters/sec), P was calculated as 24 kW assuming $e = 0.51$ ($e_{Generator}$ = 85 %, $e_{Turbine}$ = 60 %; e is usually higher and can be taken as 0.75 - 0.8). It is critical that Q and H should be measured carefully before selecting a site and the installed capacity.

SITE SELECTION

Map 1 indicates the hydro-potential in different states. The primary parameters which define the hydro-potential zones are topography, hydrology, power market area and site accessibility.

Topography

For run-of-the-stream, diversion-type hydroelectric developments, fairly steep topography is essential.

Hydrology

Suitable run-off in conjunction with topography must be available for hydroelectric development.

The primary data required for hydrologic analyses of stream flow are:

- Catchment area
- Annual steam flows
- Annual basin precipitation
- Meteorological records including air temperature, relative humidity, wind speed and evapotranspiration

Annual discharge at the hydropower site is given as:

$Q = A(P-E)$

where Q = annual run-off at the hydropower site

A = catchment area at the hydropower site

P = catchment precipitation at the hydropower site

E = annual evapotranspiration for the catchment

Hydrologists often use the following correlation model:

$Q = RA^aP^bS^c$

where Q = annual stream flow at flow site

P = annual precipitation

A = catchment area

S = slope of the catchment

and obtain the constants using multiple regression and correlation analysis. It is unlikely that hydrological data available for the Himalaya region and it may be necessary to depend on simple empirical formulae. For certain areas, data on rainfall may be available. Allowing an average of about 70 percent for evapotranspiration, we can assume $Q = 0.3AP$ cumecs.

C. R. Rao (Retired Chief Engineer CPWD) suggests on the basis of long practical experience in Arunachal Pradesh that a catchment area of 1 km^2 yields a flow of 0.5 cusecs or about 15 liters/sec (during lean months). It is worthwhile to develop such thumb rules for different regions in the Himalaya.

The preliminary information necessary for site location and hydrological studies of a mini or microhydel unit may be based on the survey of India toposheets (scale: 1:50,000) which also give an approximate idea of catchment area of the river or the stream, general slope of the river bed, and the river width. Normally, bed slopes of more than 1 in 40 suggest high potential for a mini or microhydel unit. The toposheets give an approximate idea of the hydro-potential of a particular area, based on which site studies may be made.

Bed slope and flow have to be measured. Obviously, the flow or discharge is unsteady and varies seasonally. Figure 3 represents a typical annual hydrograph. Flow may be measured during the lean months of January, February, and March. The design of hydro-generation may be based on a flow 20 to 30 percent greater than the average flow measured during lean months.

Exhaustive hydrological studies are expensive, time-consuming, and may not be worthwhile. Considering that resources and manpower are limited, it is desirable to have a larger number of sub-optimal mini or microhydel plants than a few optimally designed plants.

Various techniques ranging from the use of floats to current meters may be used for measuring discharge. The flow is measured at the site selected for the diversion weir. The velocity is measured at 0.6 *d* where *d* is the depth of the channel at different points (Figure 4) and the average discharge is calculated.

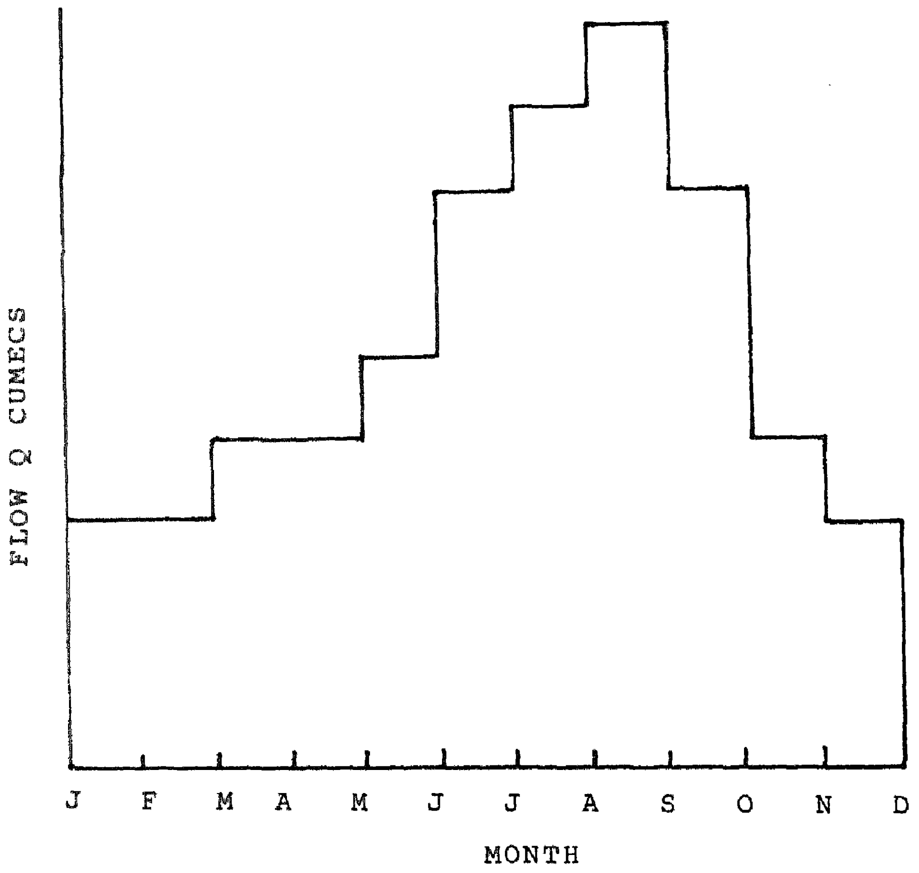
It is also necessary to collect as much data as possible about the flashfloods typical in the Himalaya region. A suitable location for the diversion weir on the stream is a flat bed from which the stream begins a steep descent in its undulating course. A 50 to 70 meter drop in the bed level over 2 to 3 km is suitable for the location of the power house.

For constructing the power channel (Figure 2) a trace cutting is done with a gradual slope of about 1:750 after having decided whether the left bank or the right bank of the river is more suitable. The forebay is generally located on the spur of a hill above the power house.

The main considerations in these selections are to ensure stability of the power channel and forebay, penstock alignment, and low costs for construction and maintenance. Needless to say, experience plays an important role in making judicious selections. A question that frequently arises in the case of small hydroelectric projects is regarding the necessity to have additional storage. For a run-of-the-river type, storage capacity of 10 to 15 minutes in the forebay is usual. The main problem that may be faced in meeting peak loads is not only diurnal but monthly as well.

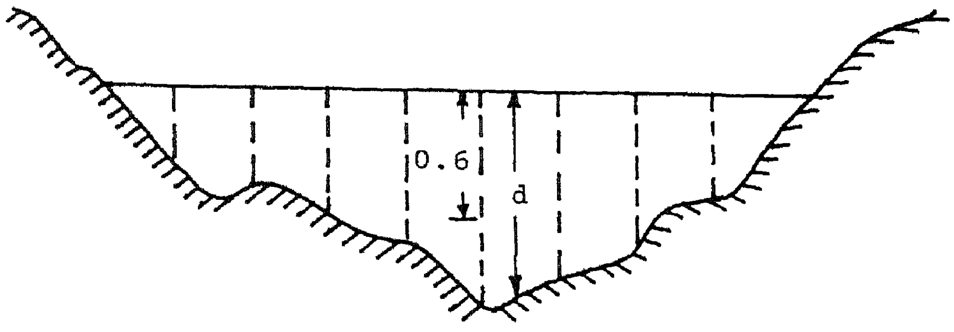
If the peak demand is 1000 kW between 6 A.M. and 9 P.M. and the average discharge can generate 600 kW, it may be necessary to meet the deficit of 400 kW by diesel generation which is costly. The off-peak demand may be 200 to 300 kW, in which case, surplus water spills over. The idea of providing additional

Figure 3



MONTHLY HYDROGRAPH

Figure 4



FLOW MEASUREMENT

storage is to store surplus water at off-peak hours in order to meet peak demand. Ideally, storage facilities should be provided. The decision depends, however, on the power market, available funds, and topography.

EXPERIENCE OF CONSTRUCTION IN THE INDIAN HIMALAYA

It has been indicated that India's experience of constructing mini and microhydel units in the Himalaya is rather limited. The Central Board of Irrigation and Power recently published a document ('Small Hydro Stations: Standardization', Publication 175, February 1985) which provides design details of SHP. References have been made in this publication to details of construction as given in Indian Standards Specifications. Whereas these specifications are useful general guidelines, local variations become the decisive factors, particularly in the hill regions.

Cost is an important criterion and it becomes prohibitive if all the specifications have to be adhered to. Engineers who have been involved in construction in the Himalaya region claim the cost of construction can be significantly reduced if local labor and materials are utilized, and variations in design made in accordance with local requirements. Access is a major problem and access roads are expensive to construct. Engineers have to decide how access roads should be constructed in difficult terrain. Shah and Moral (1983) observed with reference to Gharola Microhydel Scheme, "whereas the construction (of diversion) did not pose a problem, a jeepable road of about 2 km had to be cut through vertical rock face in some lengths at half arch as well, so as to enable the jeeps to ply so that construction materials, equipment, and penstock pipes could be taken... Experience indicates that it will be better to have equipment in crate packages that can withstand rough handling and that it does not exceed 200 kg in weight".

For diversion, the trench-type weir has been strongly recommended (Sood et al 1984) for use in hill regions. On the other hand, an engineer engaged in SHP in the Himalaya region made the following observations: "According to old practice, we have been constructing trench-type weirs. These are costly and time- consuming and at the same time, a height of 3 to 4 meters is lost in this process. The power channel after its off-take from trench-type diversion has to be secured well for a long length. This long length of protection is costly and liable to erosion, interrupting power supply ... To overcome this, it is desirable to construct a solid weir of concrete or stone masonry in cement mortar of about 2 meters in height, with suitable scour pipes at the bottom".

This observation may be pertinent to a particular area but is unlikely to be universally valid and it is here that judgment and discretion play a significant role. For example, in Rongtong Microhydel Scheme it was decided that the intake structure and diversion channel should be the trench-type weir.

The power channel is a very expensive item in mini and microhydel construction. Discussing the water conductor system in the Himalaya region, Singh (1983) observes, "The water conductor systems have included channels lined in masonry, concrete, and other ways such as wood flumes, metal flumes of thin steel pipe, and concrete pipe. Although preference for channels and flumes has been kept in mind in many places, interposition of small tunnel sections has been necessary to overcome difficult hill sections."

Rao observes, "Wherever mountain slips were anticipated, covered rectangular sections for the power channel were adopted. At some places, the covering of the power channel was done with wooden sleepers obtained from the felled trees along the power channel alignment to make use of local material and labor..."

In this context, Shah and Moral (1983) observe, based on Rongtong Microhydel experience, "It (the water conductor system) has also to be kept covered by removable concrete slabs so that no debris falls into the power channel during the rains and when thawing takes place after winter."

Once again, an appropriate decision has to be made depending on the project site. If there are possibilities of avalanche over the power channel, it has to be secured by concrete slabs despite the cost involved.

Engineers who have worked in the Himalaya agree that for penstocks, mild steel pipe joints should be welded and flanged joints should be avoided. For small microhydel plants, high density polythene pipes have been recommended.

One of the major considerations in the design and construction of mini and microhydel units in the Himalaya is desilting. Quoting once again from Bhargava et al (1983), "Intakes for high head power plants on Himalayan streams carrying very heavy sediment charge pose problems of exclusion of sediment over a wide range of particle size. The problem magnifies further in the case of small hydrostations where settling basins in the form of large reservoirs are not practical and the head available is more than 100 meters necessitating removal of very fine sediment from considerations of safety of the machines."

The need for desilting has been repeatedly emphasized by engineers who have worked in the Himalaya, although the attempt to exclude very small silt particles can be costly. An analysis for a small hydro project in Ladakh indicated that the cost of a desilting basin to exclude silt particles up to 0.2 mm would cost nearly four times as much as a basin required to remove particles of 0.5 mm and above. "It may be worthwhile," comments Narasimhan (1983), "to have turbine runner made of material of high erosion resistance or even to keep a spare runner rather than resorting to expensive desilting arrangements."

On the other hand, the recommendations of the Central Board of Irrigation and Power document (Publication 175) are:

Head	Size of silt particle to be removed should be greater than
Medium head	0.2 to 0.5 mm
High head	0.1 to 0.2 mm

Like various specifications set out in the documents, the recommendation made above may be costly for the Himalaya region with high head hydel projects. Finding enough flat space for desilting may not always be possible either.

There are, of course, a number of construction problems at high altitudes. Recalling their experience in Rukti Microhydel Scheme at Sangla village of Kinnaur District, Shah and Moral (1983) observe, "The construction of this scheme did not present difficulty during execution because of the existing road, enabling jeeps to carry the equipment and construction materials. Since the project is located at a high altitude, there was difficulty in doing the civil construction work during the winter months from November onwards. This was because the cement would not set on account of low temperature. The work was, therefore, planned so that the bulk of the construction work could be executed during the summer months." While the problems presented by mountainous areas vary widely, the account above gives a glimpse of some of the problems faced by engineers who worked in the Himalaya region in India in the recent past.

COST ANALYSIS OF MINI/ MICROHYDEL INSTALLATIONS

The major resistance to SHP seems to be its high cost per kW and low return. Different figures are quoted, ranging from Rs. 15,000 to 35,000 per kW for installation cost. In remote hill areas, cost of construction tends to go up and since the generated power has to be locally consumed, returns are low.

Cost details of six small hydel stations in hill regions have
been quoted by Narasimhan (1983) and are presented below.

Table 2: Cost details of Six Small Hydel Stations in Hill Region

S. No.	Installed capacity, in kW	Total cost Rs. 100,000	Cost/kW	Remarks
1.	2 x 500	136	13600	1.87 km water conductor
2.	3 x 5000	2150	14333	7 km tunnel
3.	750 + 250	178	17800	2.2 km open channel
4.	2 x 4000	1738	21725	3 km water conductor
5.	2 x 1000	738	36900	1 km water conductor
6.	4 x 500	787	38350	8 km water conductor

It is clear that construction costs varied from Rs. 13,600 kW to Rs38,350 kW. Rao, based on his experience in Arunachal Pradesh, claims that using local techniques and 90 percent local labor, a microhydel station on its completion used to cost between Rs. 5500 and Rs. 8000 per kW of installed capacity during the years 1976-1980. He gives the breakdown of expenditure in support of his argument.

	Approx expenditure per kW installed capacity	
1. Civil Works such as Diversion Weir, Channel, Power House, and Forebay	Rs. 2000	30%
2. Penstock Pipes along with Anchor Block, etc.	Rs. 1000	15%
3. Power House Equipment such as Turbine, and Alternators	Rs. 3000	40%
4. Miscellaneous such as Approach Roads	Rs. 1000	15%
	Rs. 7000	100%

Rs. 7,000 per kW during 1976-80 appears to be on the low side (allowing for escalation, this amount would probably come to Rs. 14,000 in 1986) and Rs. 9000/kW would have been closer to the mark. Figure 5 represents approximate cost distribution for mini and microhydel plants of a few typical ratings.

In this context, a set of data is presented pertaining to manufacturing cost, operation and maintenance charges, and cost of generation for 16 mini/microhydel projects in Arunachal Pradesh during 1971 and 1981. This example is chosen because a large number of installations in the entire spectrum of micro and minihydel plants were commissioned within 10 years (1971 - 1981) and necessary data was available. Figure 6 is a plot of cost/kW against kW of installed capacity. In two cases in the microhydel range, cost/kW exceeded Rs. 32,000. In all the other cases the cost was within Rs. 15,000/kW with an average cost of Rs. 8850 per kW. One 10 kW microhydel plant was set up at an expenditure of Rs. 132,000 and hence the two cases referred to above could be ignored and fit an approximate exponential curve (y=A+BE-Kx) developed as shown. This exponential gives the average cost/kW for a certain installed capacity and indicates that microhydel units are more costly per kilowatt than minihydel units.

Stray cases of high cost/kW will invariably reflect difficult terrain. However, experiments carried out in Nepal with home- made crossflow turbine (or centrifugal pump operated in an inverted mode), high density polyethylene pipes for penstock, and the utilization of local material and labor, indicate that it is possible to bring down the cost/kW for microhydel units significantly.

Cost Comparison between Large and Small Hydel Plants

Unfair comparisons are frequently made between large hydropower (LHP) and SHP. Apart from ecological questions and many other intangible factors which

APPROXIMATE COST DISTRIBUTION FOR CONSTRUCTION OF TYPICAL MINI/MICRO HYDEL SCHEMES

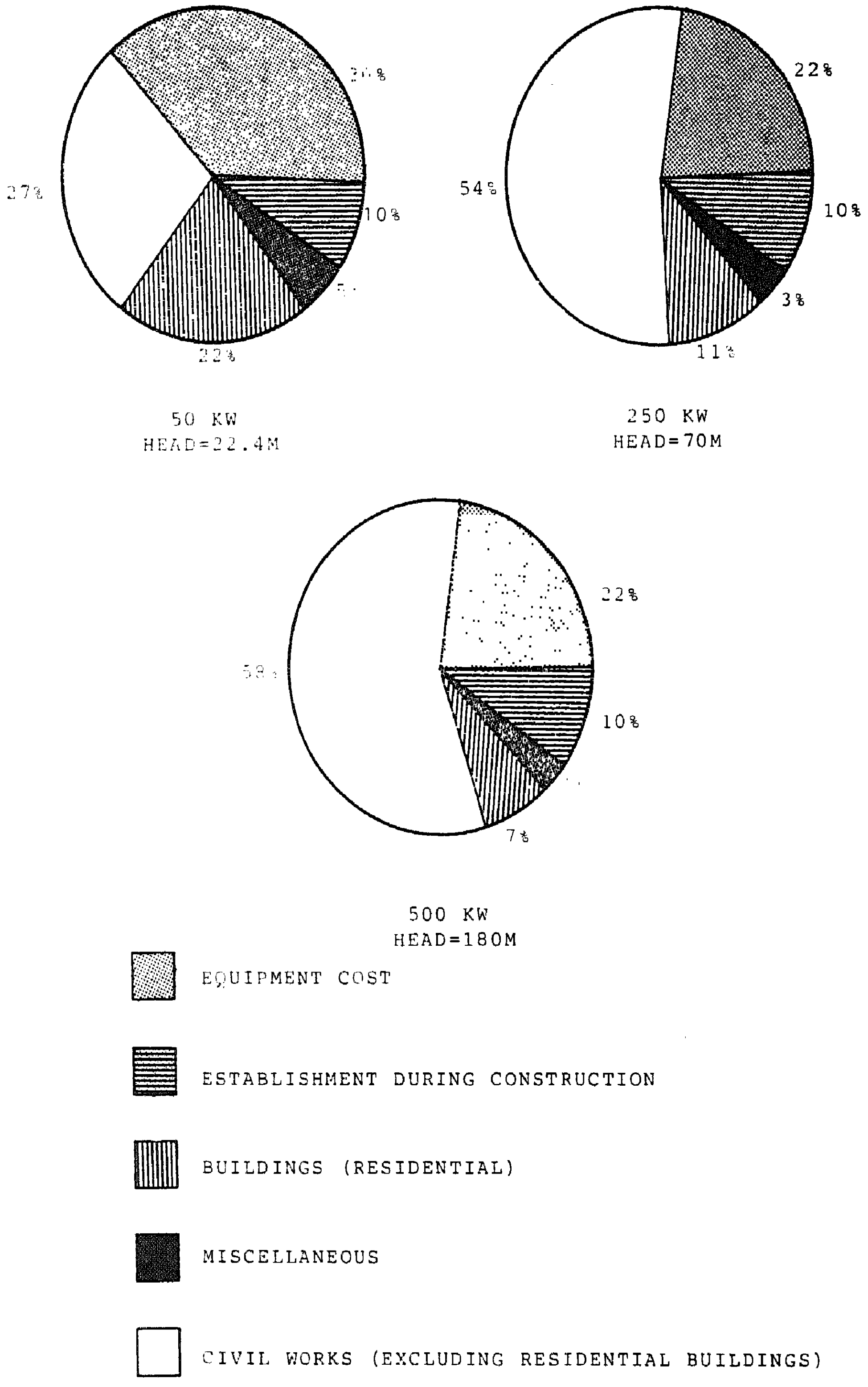
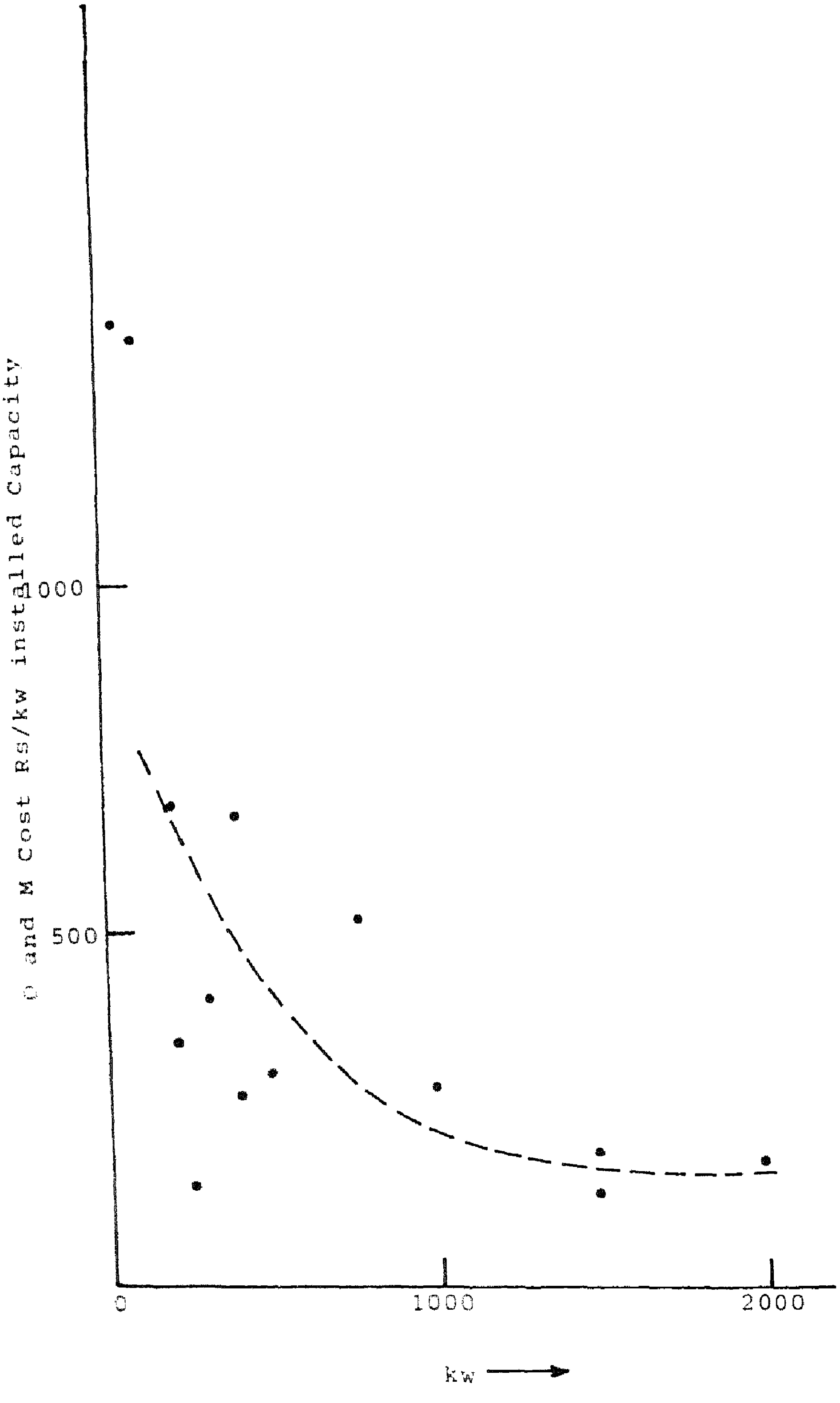


FIG. 5



VARIATION OF COST PER KW FOR OPERATION AND MAINTENANCE WITH INSTALLED CAPACITY

FIGURE 6

usually go against large hydel projects, SHP stands on firm ground even on cost/kW comparisons.

It is essential that LHP costs take into account the cost of transmission and distribution and high power loss in the process. If one includes the cost of T and D, cost delivered power from LHP comes to between Rs. 20,000/kW and Rs. 25,000/kW.

Yet another factor that needs to be considered in this context is the relative time taken for construction of large and small hydel plants.

A large hydroplant takes about 10 years to complete, whereas a mini or microplant should not take longer than two to three years. Apart from the high rate of escalation, the opportunity cost of delayed availability is significantly in favor of SHP and should be taken into account. A simple example illustrates the financial loss incurred when diesel generation is resorted to because large hydel plants take so long to construct. If small hydel power were generated instead, the value of early availability (v.e.a.) of 1 kW of power per year would be:

v.e.a. = 1 x 8760 x PF x LF (1-LOSS) x (C_D - C_m)
where PF = plant factor 0.5 say
LF = load factor 0.3 say
Loss = T and D loss 0.2
C_D = cost/unit of diesel generation Rs. 2.50
C_m = cost of hydel generation = Rs. 0.75/unit
v.e.a.= Rs. 8760 x 0.5 x 0.3 x 0.8 x 1.75 per kW per year Rs. 1840/kW/year

If a LHP takes seven years longer to construct compared to a SHP, one should add Rs.12,880/kW, even at fixed cost, to the cost of construction of LHP.

This rather lengthy discussion on cost is prompted by remarks frequently made by engineers and administrators who maintain that high cost and high cost of generation (unit cost) are the main deterrents to the growth of SHP.

Cost of Generation

It is known that the load factor of mini or microhydel power is low unless it feeds a grid. (An average load factor of 20 percent or 0.2 means that only an average of 20 percent of the installed capacity is utilized.)

It is inevitable that the power market in the Himalaya region will be restricted since the villages are often isolated and scattered. The fact that there is little industrial activity makes the load factor poor and boosts the cost per kWh. For example, the total units generated during 1981-82 in Arunachal were 15.06 million units for an installed capacity of 9160 kW. The load factor $15.06 \times 10^6/(9160 \times 8760) = 0.1877$ was a significant improvement from 0.125 of 1979-80. Obviously load grew over the years, resulting in larger consumption.

If the mini or microhydel only feeds lighting load, the load factor will be inevitably low. On the other hand, if electricity is utilized for irrigation and small-scale industries, consumption and, therefore, load factor will obviously improve. Incidentally, load factor in most of the rural areas electrified so far in India is also about 0.2; thus, the load factor of 0.1877 in Arunachal Pradesh is not so poor.

Operation and maintenance charges appear to be a burden when the units sold are not large. The O and M charges in Arunachal during 1981-82 came to about Rs. 35,00,000 and the units sold were 15.06 x 10^6. The unit charge for O and M came to over 23 paise per unit (100 paise = 1 Rupee) and 4.34 percent of the cost of installation (which is higher than the 2 percent frequently assumed). Figure 7 shows that O and M cost/kW decreases with installed capacity as may be expected. In fact these are almost inversely related ($Y = k/x$). It is therefore necessary to make microhydel units rugged, even at the cost of efficiency, so that O and M costs may be reduced. In Table 2 the cost of generation has been computed on the basis of 8 percent interest and 3 percent depreciation on capital investment. Take the case of Itanagar during 1981-82 when 1.75 million units were sold.

Capital invested was	Rs. 9,668,000	
Interest and depreciation at (8+3)%	Rs. 1,073,480	(1)
Operation and Maintenance	Rs. 401,446	(2)

Total, adding (1) and (2) =
Rs. 14,64,926 x 10^6
Cost per unit = 83.7 Paise

Clearly, this is high and calls for subsidy. It may be pointed out in this context that the urban consumers in All Electric Homes (AEH), becoming increasingly popular in Karnataka, also receive power at a subsidized rate. If connected load is 3 kW and the consumption at peak hours is 2.5 kW (an immersion heater is rated at 1.5 - 2 kW) the investment cost would have been Rs. 50,000 (at a low value of Rs. 20,000/kW delivered power).
At 11 percent interest and depreciation and 2 percent operation and maintenance cost, the total annual revenue a consumer should pay on average is Rs. 7150 or Rs. 600 a month for about 300 units of electricity consumed. Cost per unit should be Rs. 2 which is not paid in India. In Karnataka, it is 47 paise/unit for domestic consumption.

Microhydel vs. Grid Extension

In the Himalaya region, there may be a choice between developing a microhydel unit and extending an 11 kV grid for the electrification of a village or a group of villages. In mountainous regions, grid extension is never easy. Apart from problems presented by the terrain, felling of trees may be involved. On the other hand, extending the grid improves the load factor by extending the power market, and for certain distances and power, annual cost is clearly less. Sen Gupta and Gromard (1984) presented a simple graphical method for deciding between these options based entirely on cost criterion.

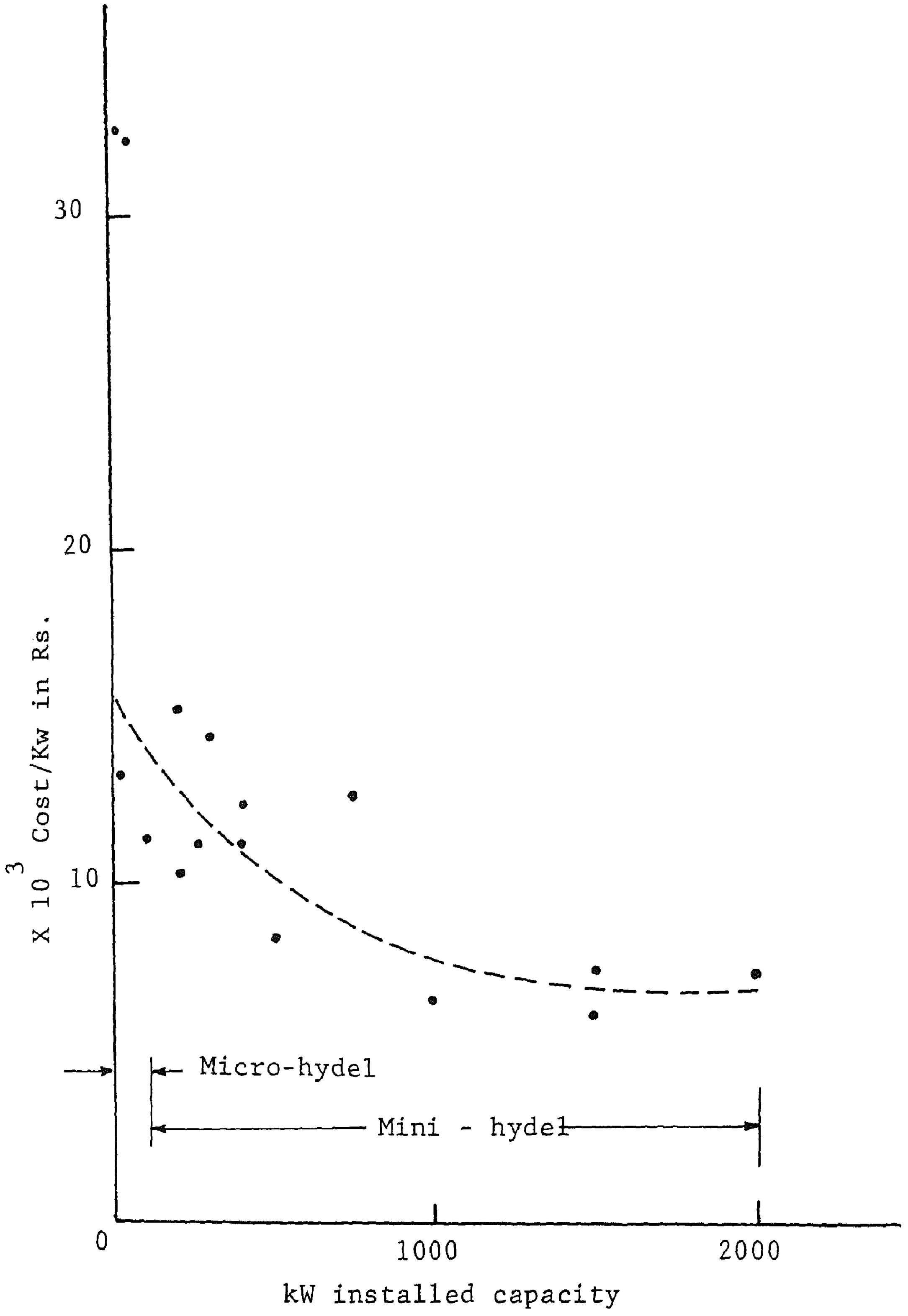
Annual costs may be calculated as:

$$A_g = C_{11kV} \text{ x } 8760 \text{ x } LF \text{ x } P + 0.01\, r_g (1 \text{ x } C_L + C_T)$$

where

C_{11kV} = cost of electricity per kWh at the 11 - kV level
LF = load factor (assumed 0.2)
P = peak load in kW required for the village

Figure 7. Variation of Cost per kW with Installed Capacity



r_g = percentage interest on the capital investment depreciation and O and M (assumed 12 %)

C_L = cost of distribution line per km (assumed Rs. 25,000 for Weasel conductor)

C_T = cost of transformer (Rs. 12,000 average)

l = distance of the center of the village from the nearest 11-kV feeder in km

Annual cost of supply with a microhydel unit A_m

$A_m = 0.01 r_m C_m P$

where r_m = percentage interest on the capital investment depreciation. O and M (assumed 15% = 8% + 3% + 4%)

Cost per unit is calculated below:

C_g = cost/kWh for grid

$$= \frac{A_m}{P \times LF \times 8760}$$

C_m = cost/kWh for microhydro

$$= \frac{A_m}{P \times LF \times 8760}$$

Figure 8 compares the cost/kW for these two options.

For example, a microhydel unit costing Rs.10,000/kW is always to be preferred to line extension. If cost/kW of microhydel is Rs. 25,000, it is economical up to 30 kW if the nearest grid is more than 10 km away. As regards cost/unit is concerned Figure 9 clearly indicates that unit cost for grid supply decreases with increasing power and the break-even points may be obtained from these graphs. It is certainly worthwhile making a study, where appropriate, to decide between grid extension and setting up of new microhydel units. It is needless to mention that technical or ecological constraints may override cost considerations.

DISCUSSIONS AND CONCLUSIONS

A substantial part of this paper has been devoted to cost analysis of mini or microhydel projects, to make the point that even on mere cost considerations, these projects are justifiable. It is necessary at this stage to emphasize that electrification of the numerous villages in the Himalaya region is essential, irrespective of cost considerations, and harnessing waterpower seems to be one of the most sensible solutions to the problem.

The major objectives of electrification are to provide:

1. Lighting and save kerosene generally used at present
2. Lift irrigation
3. Help with the development of cottage industries
4. Help with the setting up of industries such as poultry farming, fruit canning, tea, and other agrobased and forest industries
5. Diesel savings where diesel generation is being resorted to for strategic purposes

In most areas in the Himalaya, electrification will have to come from mini and microhydel sources.

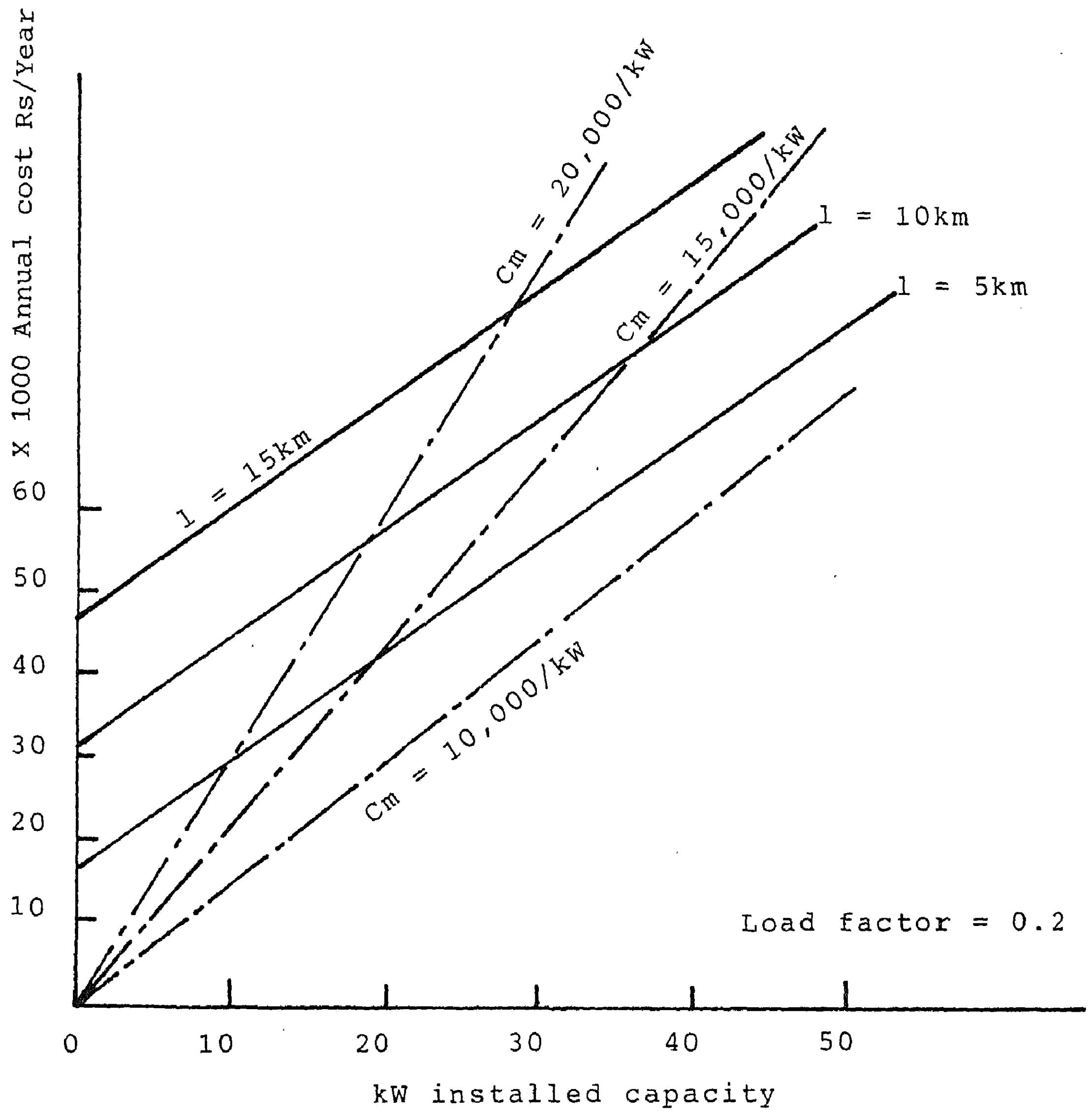
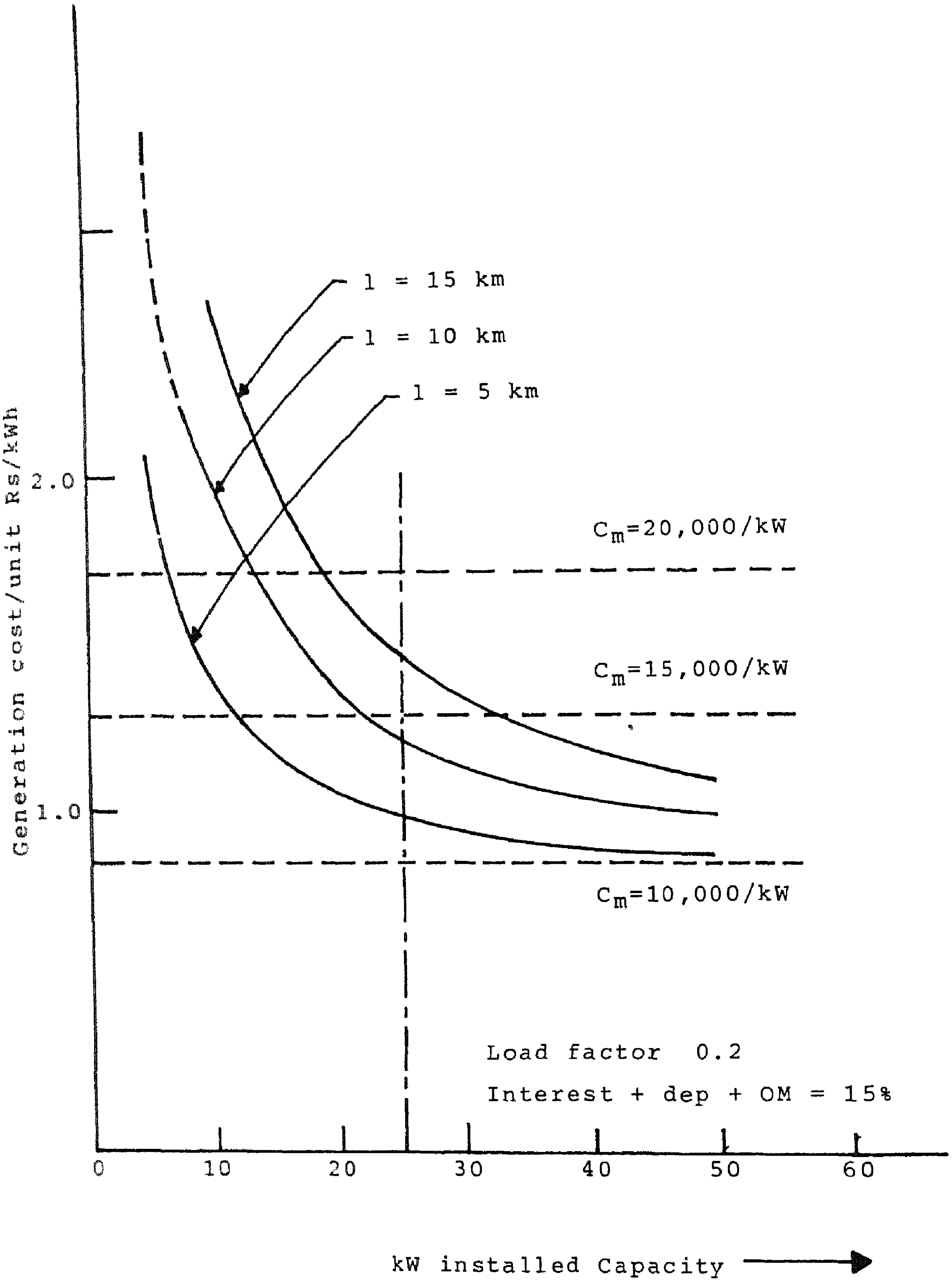


Figure 8. Variation of Annual Cost with Installed Capacity for Grid Extension and Microhydel



VARIATION OF GENERATION COST PER UNIT WITH INSTALLED CAPACITY, FOR EXTENSION AND MICROHYDEL INSTALLATIONS.

FIGURE 9

Large hydroelectric projects such as the Karnali (3800 MW) project, (a proposed Indo-Nepalese venture) or Pancheswar (1000 MW) at the Indo-Nepal border will not and in most cases cannot, meet the needs of these Himalayan villages. Besides, the wisdom of developing such a large scheme needs to be ascertained from the ecological viewpoint.

It is, however, true that electrification alone will not bring about the developments listed above unless other vital inputs are made as a deliberate policy to develop these areas. But lighting itself can bring about substantial change in the lifestyles of the villagers.

Rao, who was involved for many years in a number of mini and microhydel projects in Arunachal Pradesh, states that following the introduction of street lighting, villagers could work late hours in fields and instead of spending evenings in their dark homes drinking country liquor for and getting into brawls, they would go outdoors to the marketplace which distinctly reduced drinking and improved the lifestyle of the villagers. One major impact of electrification, Rao observes, was reduced violence on housewives--violence which invariably followed excessive drinking.

Lift irrigation provided in some villages spared the women the strenuous work of having to collect water from long distances. For these benefits alone, cost considerations should be set aside and mini and microhydel power developed in as many places as possible.

In conclusion, the following recommendations are made:

1. To consider setting up a Central Public Sector Corporation such as National Small Hydroelectric Power Corporation (NSHPC) [like the NTPC and NHPC] directly under the Department of Power. This will undertake the survey, design, and installation of SHP throughout the country in conjunction with the Rural Electrification Corporation (REC). Special funds have to be allocated for the development of SHP.

2. With regard to the development of SHP in the Himalaya region, extensive survey of the sites listed needs to be carried out and a work schedule prepared.

3. Training schemes need to be arranged to train engineers to utilize local materials and labor as much as possible in the execution of these projects. This will significantly lower costs. Operation and maintenance should be entrusted to local people trained for the purpose.

4. Although agro-industrial development has to be the ultimate objective, lighting and irrigation should be the immediate tasks following the setting up of the mini and microhydel plants. Provision of domestic connection (one light point) should be made free for the low-income group (like the Bhagyajyothi scheme in Karnataka).

Finally, and most importantly, attitudes towards rural electrification and development of micro/minihydel for the rural community in the hills or the plains must change. These services are **not to be considered as a favor**, and grudgingly carried out because they are included in the 20-point program.

Rural electrification in India, an apparently low-return investment, has provided irrigation and helped to turn a food-deficit country into a food-surplus country. In a similar way, development of the Hindu Kush-Himalaya will bring the people in those areas into the national mainstream, give them a stronger sense of belonging, and alleviate many border problems that we have been faced since independence.

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ENDNOTES

1. The data has been obtained mostly from the Central Electricity Authority (CEA) of India. As may be expected there is a significant amount of overlap between the data from other sources and there are some discrepancies as well.

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USES OF HYDRAULIC RAMS (HYDRAMS) IN HILL AREA

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INTRODUCTION

Backwardness of the hill areas in India is attributed mainly to peculiar geographical factors, varying agroclimatic conditions, and lack of communication. A large percentage of the terraced agricultural land in the hills is situated above water sources, so water goes unused due to unavailability of suitable water-lifting devices. The existing irrigation facilities in the hills are gravity channels and tanks which provide irrigation to a small percentage of land below the diversion-point level of the stream. Lift- irrigation projects operated with electric and diesel pump-sets have hardly achieved tangible results due to their high recurring expenditure and maintenance costs. Difficulties of communication and after-sales services are some of the bottlenecks to making electric and diesel-operated systems acceptable in the hills where small land holdings exist.

The energy crisis today has led scientists and technologists in many countries to explore new sources of energy and make better use of existing ones. In India, efforts are being made to harness energy from sun rays, biogas, and tidal waves through research and development work. With increasing demand for power in industry, agriculture, and domestic uses, any device which can work without relying on power from outside is welcome. The hydraulic ram, commonly known as hydram, therefore assumes importance in meeting increasing water requirements in the hills.

The hydram lifts water using energy from flowing water with a small head. It requires no external prime mover, like a motor or an engine, for operation. The overall efficiency of the hydram in terms of energy utilization can be as high as 98 percent and water can be lifted to a height 30 times the water head. The mechanical efficiency reaches 98 percent (from 4 to 10 times the working head); and it comes down to 35 percent at 30 times the lift of water head. Normally 3 to 25 percent of the water flowing through the ram is lifted at various lift magnifications. Since the ram does not have rotating or reciprocating valves, maintenance costs are negligible and little technical expertise is required for operation. Hydram technology has tremendous scope to help meet pressing water requirements both for irrigation and drinking water in the hills.(Figure 1)

Hydram Efficiency

Mechanical efficiency is a measure of the percentage of successful transfer of energy from one form to another. Similarly, the volumetric efficiency is calculated by dividing the quantity of water raised by the hydram from the quantity of water supplied in the machine. As shown in Figure 2, in the

WORKING OF HYDRAM MACHINE

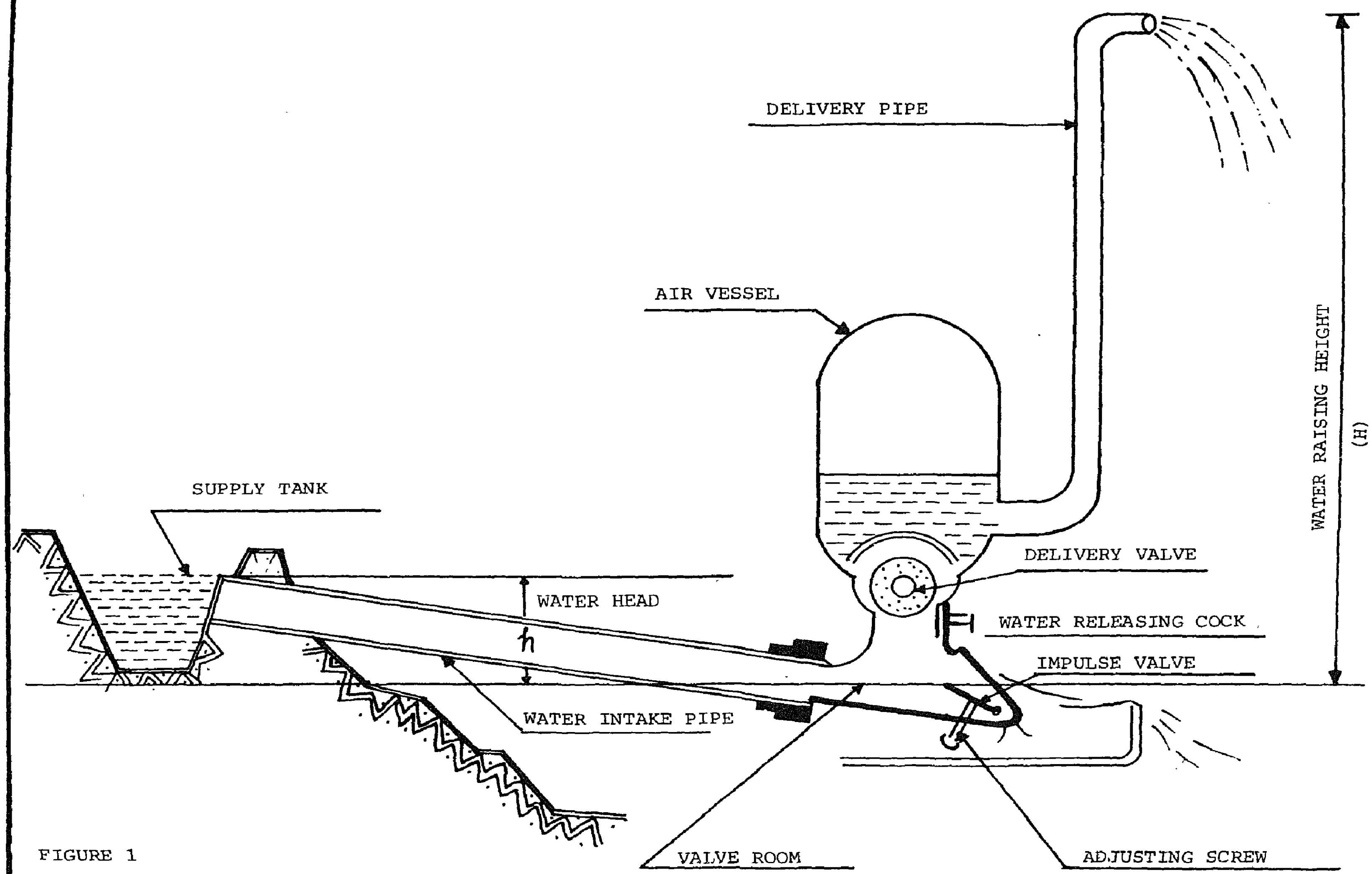
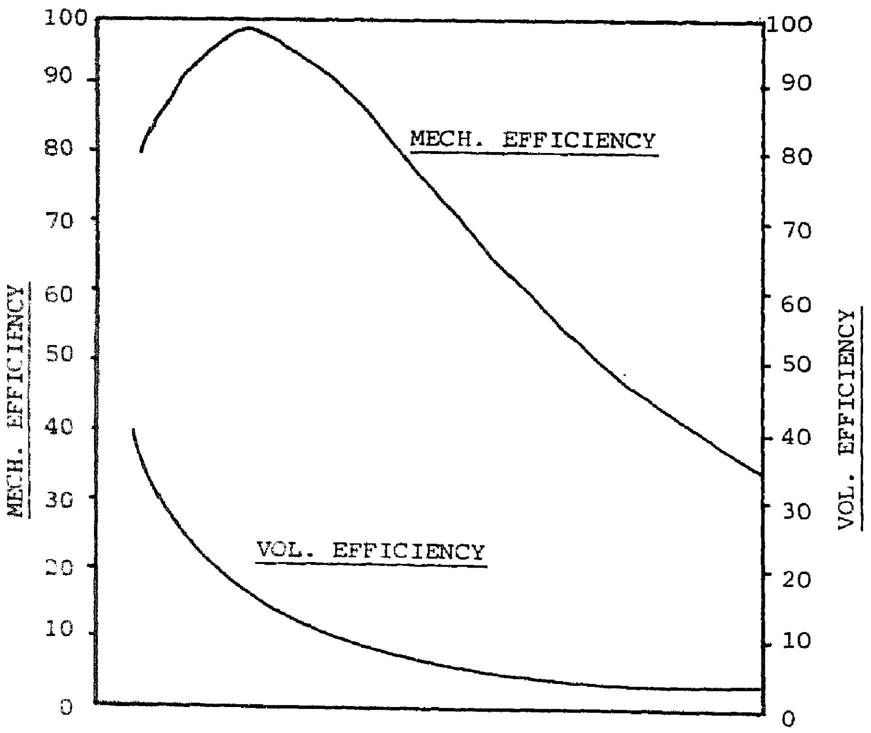


FIGURE 1

LEFT MAGNIFICATION FACTOR	MECH. EFFICIENCY	VOL EFFICIENCY
2	80	40
4	92	23
6	98	16.33
8	97	12.126
10	94	9.4
12	85	7.08
15	75	5.00
20	80	3.0012
25	45	1.8009
30	35	1.166

EFFICIENCY CHART



LIFT MAGNIFICATION FACTOR. (OISCA MAKE)

FIGURE 2

case of the Oisca hydram, the mechanical efficiency reaches a maximum of 98 percent at six times the lift of the working head and 35 percent at 30 times the lift of the working head. The volumetric efficiency obtained is 40 percent at twice and 1.16 percent at 30 times the lift of the working head. The maximum mechanical efficiency of Blake's type of hydram is 72 percent at lift magnification of 4 and 4 percent at lift magnification of 24.

2.5 Sizes of Hydram pump

Hydram pumps are manufactured in many sizes, including 12"x6", 8"x4", 6"x3", 4"x2", and 2"x1". Pump size is determined on the basis of the size of intake and delivery pipe fitted with the valve room and in the vessel. Discharge available from various sizes of pumps at different lift magnification factors are given in Table 1.

Table 1: Discharge in litres per minute of various sizes of Oscia make hydram at various lift magnifications

Lift Magnification	2"x1"	4"x2"	6"x3"	8"x4"	12"x6"
2	27	109	240	412.5	1000
4	18.5	76	190	350	840
6	14.2	60	190	300	680
8	11.0	46	158	300	500
10	9.0	38	111	210	420
12	8.5	34	102	190	318
15	6.6	28	88	160	280
20	5.0	18	70	130	180
25	3.8	16	64	110	160
30	2.6	11	60	85	140

Survey and Pumping Unit Design

Before preparing the hydram project, it is necessary to consider the following:-

- Vertical fall from source to hydram
- Vertical lift from pump to delivery spot
- Quantity of water available in the stream
- Quantity of water required at delivery spot
- Delivery pipe length from pump to delivery site
- Arrangement for unused water disposal
- Necessary space for laying the desired length of intake pipeline
- Minimum length of supply channel required to create the working head and also safety from flood, landslides, etc.

For the selection of proper hydram size, four main factors are taken into consideration: quantity of water required at delivery site; quantity of water available in the stream; the lifting height; and working head. First, the quantity of water required at the delivery site is calculated. Then, the flow of the stream is measured. The lift magnification factor can be obtained by dividing the delivery height with the working head. Taking into consideration the requirement for water coupled with the lift magnification factor, the suitable size of hydram may be selected. If one hydram machine is not enough to meet the requirement, a battery of hydrams can be used in one project; the intake pipe is then joined to force the water in one pipe. A battery of two hydrams is shown in Figure 3. In Appendix 1, the water lifting capacity of different sizes of hydrams at various lift magnification factors in 24 hours are calculated. The area irrigated per day for various depths of irrigation is also shown.

Hydram Project Construction and Installation

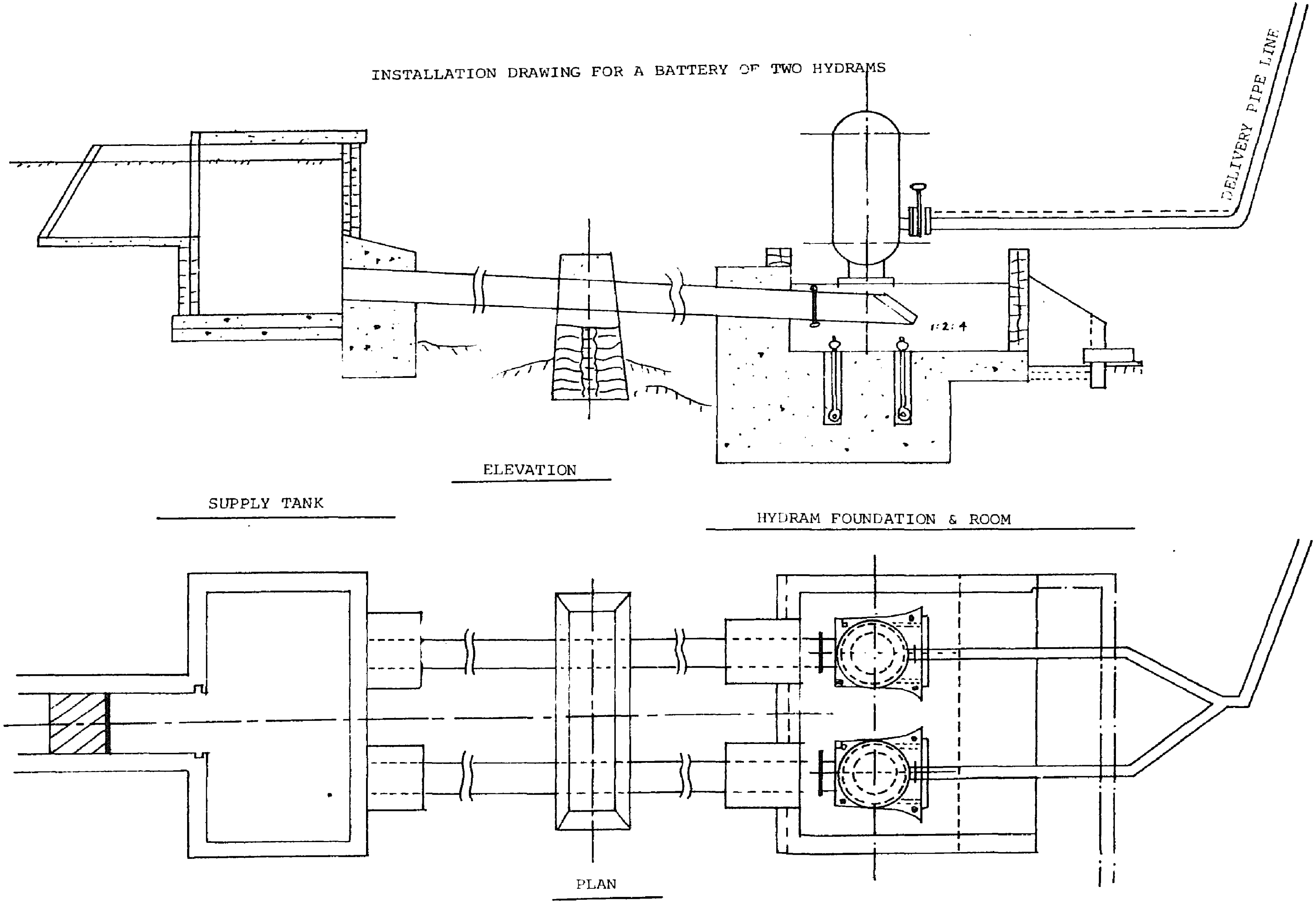
The following civil and mechanical work is required for setting up the hydram pumping unit:

Diversion Work. At the source of water diversion, work is done to divert water into the supply channel so that minimum damage is caused in the event of a flood.

Supply Channel. To create the desired working head and to bring the water where the hydram is to be installed, the water is carried from the source through the channel. This channel, constructed with random rubble stone masonry or concrete, is called the supply channel. This can be opened or closed as need be. The cross-section of the channel is designed to be suitable to the requirements of the hydram. The layout of the supply channel is done so that chances of damage by landslides and floods are reduced to a minimum.

Supply Tank. This is a small tank constructed at the end of the supply channel to regulate the flow of water into the intake pipeline. It is constructed so at least a head of at least two to three feet of water is always maintained above the mouth of the intake pipe. The supply tank creates discontinuity in pressure between the water of the supply tank and the water of the intake pipe, thus resulting in negative pressure waves moving backward toward the impulse valve and

INSTALLATION DRAWING FOR A BATTERY OF TWO HYDRAMS



FIGURE

closing it. It should be strong enough to resist the vibration of the pipe.

Hydram Foundation. Hydrams are anchored with the foundation bolt in a three-to four-foot deep reinforced concrete foundation. The foundation three-to four-foot should be strong enough to withstand the vibrations. It is observed that any shock-absorbing device at the intake joint of the hydram creates problems. Small vibrations concentrated entirely at the foundation may break the foundation bolt and are liable to damage the machine also.

Intake Pillars. When the machine is in operation, the vibrations are spread along the length of the intake pipeline up to the supply tank. If the pipes are not properly anchored, it may break the joints or damage the supply tank. Therefore, the entire pipeline is anchored in the reinforced concrete pillars.

Intake Pipeline Fitting. Also called the drive pipe, this should be strong enough to withstand tremendous water hammer pressure. It is made of steel, preferably galvanized. It is necessary to keep the diameter of the entire pipeline uniform and a minimum number of joints is advisable. The intake pipe is laid according to the design recommendation of the hydram. The Oisca design requires the length of the intake pipe to be eight times that of the working head, and five to six times the working head in others. The intake pipeline should be straight and leak- proof. Mild and ungalvanized pipes require coating of anti-corrosive paint year after year.

Delivery Pipeline. The delivery pipeline is used to carry pumped water to the delivery spot. The layout of this pipe is such that minimum joints and bends are used to keep efficiency high. The diameter of the delivery pipe is reduced at different lift magnifications. Like the Oisca make, the diameter of the delivery pipe is kept to half the intake pipe up to 10 lift magnifications; between 11 to 20, it is one-fourth; and between 21 to 30 times, it should be one-sixth of the diameter of the intake pipe. In Blake and Wama's designs, the sizes shown in Table 2 are used if the pipeline exceeds 250 meters. For shorter lengths, the appropriate diameter is chosen.

Table 2: Diameter of Intake and Delivery Pipe in Blakes/Wama type Hydram

Size of Intake Pipe	Diameter of Delivery Pipe
(inches)	
.75	.375
1	.5
1	.75
1	1
2	1
2	1
3	1
4	1
5	2
6	2

Being flexible, polythene or plastic pipes are not suitable. They also have joining problems and remain exposed to weather. It is, therefore, advisable to use galvanized iron pipes.

Storage Tank. Hydrams work round the clock with no interruption. If desired, water can be stored at night. Tank capacity can be decided on the basis of expected quantity of water required for further use.

If the hydram is used for irrigation, channels are also constructed in the field to distribute water properly. Concrete or pre-cast channels are suitable as these require minimum space and are also easy to construct. Since the quantity of pumped water is limited, sprinklers should be used for judicious distribution.

Pump Operation and Maintenance

1. When the water reaches the intake pipeline and accelerates its speed, the impulse valve is closed. The valve needs to be pushed back by the starting handle. Consequently, the water is released and the impulse valve will automatically close due to the pressure of incoming water in the valve room. After repeating the motion of valve two or three times, the valve starts moving, making the pump operational.

2. The air entering through the impulse valve improves efficiency of the pump. Drained water should be adjusted to a height allowing entry of the air to the valve room. If the breathing is more than required, the quantity of water raised has to be reduced. Air breathing in lesser quantity will also reduce water raising efficiency. Therefore, the height of the surface of drainage water is adjusted to keep the efficiency high.

3. Beating counts of impulse valve or beating frequency also effects the water raising efficiency of the hydram. Beating counts through the screw located in the impulse valve are adjusted for efficiency.

4. The weight of the impulse valve is required to be added or subtracted so that water in the drive pipe obtains maximum velocity before closure. This ensures maximum conversion of available energy into raised water.

5. In the intake pipe, joints must be kept absolutely tight and the impulse valve and delivery valve in the hydram tightened properly. A slight leak seriously impairs the efficiency of the machine.

6. For the stoppage of the pump operation, the impulse valve must be held steadily for five or six seconds and the valve will then cease functioning. If the water feeding is stopped, then the pump will come to a grinding halt also.

The pump can operate for 20 to 30 years if the following points are kept in mind for proper maintenance:

1. Keep the water source in good shape by maintaining the diversion works, supply channel, and other civil works.

2. Remove the silt from the supply channel, supply tank, and hydram room, as and when required.

3. After every 24 hours of operation, check the nuts and bolts of the hydram machine.

4. Keep the intake and delivery pipeline leak-proof.

5. Change the rubber pad of the impulse and delivery valve when necessary.
6. Paint the air vessel with anti-corrosive paint.

Project Cost

The cost of the hydram project ranges between Rs.80,000 and Rs. 150,000 depending on the size of the hydram and site of the project. The cost of hydram equipment is estimated to be 15 percent of the total expenditure on the project; the rest of the expenditure is for civil work, such as diverson work, supply channel, supply tank, delivery tank, the cost of the pipeline, and installation work. The cost in terms of area irrigated is estimated at about Rs. 20,000 per hectare. The average total cost of various sizes of hydram units are as follows:

Comparative Costs

Compared to diesel engines or electricity-driven engine pump sets, hydrams are the cheapest mode of lift irrigation. It is also economical in comparison to the gravity channel system, as the latter requires a long gravity channel. Maintenance of long channels is a costly affair.

In India, investment in irrigation projects is determined by the cost-benefit ratio. Presently, the irrigation cost in gravity channels is estimated at Rs. 20,000 per hectare. For electric and diesel-operated pumping units, the cost is estimated to be Rs. 25,000 per hectare. There is, however, no estimate fixed for hydram projects. The capital expenditure and operational and maintenance costs per hectare per year are given below. These indicate that irrigation through hydrams is more economical than other sources of irrigation, including the gravity channel.

Scope for the Hydram

Innumerable flowing water sources in the Himalaya region, if tapped properly, can provide a vast energy source. They can be fully utilized through hydrams for irrigation and meeting the drinking water needs of villages at high altitudes. The U. P. hills can boast to be the pioneer in setting up more than

Table 3: Cost of Hydram Project by size of Hydram Unit

S. No. Particular of work	Size of Hydram Unit		
	4" x 2"	6" x 3"	8" x 4"
		Cost in Rs.	
A. Mechanical work			
1 - Hydram Machine	9500	14000	19000
2 - Intake pipe	7000	15000	22000
3 - Delivery pipe	8500	13000	17000
Total	25000	42000	58000
B. Civil work			
1 - Diversion work	3000	5000	95000
2 - Supply channel and Chamber	24000	35000	42500
3 - Foundation	10000	13000	15000
4 - Storage Tank and Distribution System	18000	25000	25000
Total	55000	78000	92000
Grand Total	80000	120000	150000

Table 4: **Comparison of cost of investment, operational and maintenance cost in Rs. per year per hectare**

Item	Gravity Canal	Electric	Diesel	Hydram
A. Investment cost per hectare	20000	25000	25000	20000
B. Operational cost per hectare				
i. Depreciation per year - Canal 10% Diesel/relectric 7%, Hydram 5%	2000	1750	1750	1000
ii. Interest 10%	2000	2500	2500	2000
iii. Overhead 2%	400	500	500	400
iv. Fuel/electric	Nil	500	1400	Nil
v. Maintenance 2.5% others	500	500	625	500
Total	4900	5750	6775	3900

350 units during the Fifth Five-Year Plan period and many more are planned for implementation during the Seventh Plan. The projected schemes can be further augmented subject to the availability of resources; for this, a detailed survey needs to be done. Land 200 to 250 feet above the water source can be irrigated through hydrams. Beyond this height, schemes may be prepared on the basis of a cost-benefit ratio.

Report of the Central Team

A team of experts and planners from the Central Government Ministry of Agriculture and Irrigation, Planning Commission, Ministry of Home Affairs, and the State Governments of Jammu and Kashmir, U.P., Sikkim, Assam, Manipur, and Tamil Nadu, besides the Indian Council of Agricultural Research, Planning Research and Action Division, U.P., and Agricultural Refinance Corporation, visited the Garhwal region to assess the general utility of hydraulic rams in the hill area. Following is the summary of observations and conclusions:

- The team was impressed with the utility in areas where gravity irrigation is not possible or is expensive. The hydraulic ram is considered to be economically feasible for hill areas.

- Sprinkler irrigation is considered useful in areas where the leveling of land is not possible or where irrigation water must be highly economized.

- The farmers had not been adequately trained to make the full use of irrigation. Extension support for growing improved varieties of crops and application of fertilizers and agro-implement practices were missing.

Evaluation

A case study of the hydram sprinkler at the irrigation pilot project, Gadaura District, Chamoli, U.P., was conducted by the Planning, Research and Action Division of the State Planning Institute, U.P., Lucknow, in May 1977. Extracts from the conclusions and recommendations of the division are as follows:

Conclusions

1. The Gadaura Hydram project has a capacity to raise water to the height of 225 feet from the source, and irrigation is possible in fields at this elevation to the extent of 20 acres.

2. The comparative analysis of the cost-benefit ratio of hydrams and other traditional means, in relation to capital investment and cost of maintenance, reveals that the installation of hydrams is economical.

3. The cost-benefit ratio, pay-back period, and internal rate of return of the hydram project with a lifespan of 20 years and potential of 20 acres is = 3.3:1, 4 years and 40.5 percent respectively, which may be considered highly economical from the point of view of speedy multiplication.

4. As a result of installation of hydrams in Gadaura, considerable changes were brought about in cropping patterns. *Manduwa*, one of the common crops of the hills, has been almost eliminated.

5. The installation of hydrams has shown a favorable impact on the sowing of improved varieties of wheat and paddy.

Recommendations

1. The farmers must be persuaded to make full use of irrigation potential, which is far behind actual irrigation capacity.

2. *Manduwa* and other uneconomical crops may be gradually eliminated and cash crops may be included in the cropping pattern.

3. Small, scattered, and fragmented agricultural holdings are mainly responsible for non-utilization of irrigation potential. Hence, consolidation of holdings may be explored to raise productivity in the hills.

4. Due to poor economic conditions, the majority of the farmers are not favorably responding to the improved agricultural program and to the maximum use of irrigation potential. In such cases, some economic assistance in the form of seed or fertilizer, besides irrigation water, may be

provided.

5. The possibility may also be explored for developing a suitable local organization for water management and operation of the scheme. Training to develop management capabilities should be provided.

Other Uses of Hydram

Hydram, or micro-hydropower, has many other uses. For example, small flour mills, rice hullers, oil expellers, and other cottage industries such as sawmills can run with the help of watermills. More than 75 percent of the intake water in hydrams goes to the river. The unutilized water can be used further to generate micro-hydropower for other purposes. The watermill can also be connected directly with the supply channel or hydram project as need be.

A successful experiment has been made on this at Chandroti, in Dehra Dun District, where a turbine-type watermill is connected with the supply channel of the hydram for running the flour mill, rice huller, and oil expeller. A generator is also installed at the Chandroti Project for generating electricity.

Constraints

Usefulness of hydrams is well known in the hill areas. How- ever, remedial measures to overcome constraints faced in installation and operation must be considered.

- There have been reports of improper installation, maintenance, and operation of hydrams due to a dearth of trained personnel at the project site. For achieving full benefits of the hydram scheme, the field staff is supposed to man the operation of the hydram to make irrigation facilities available.

- In the absence of Indian Standards Institution specifications and quality control, manufactures of the hydram machines have their own designs. To avoid diversity in design and to facilitate interchangeability of components, efficient equipment designs should be standardized.

- Short supply of hydram machines, steel pipes, and cement, delays completion of the projects which in turn escalates project costs. The existing procurement procedure is time-consuming and does not provide quality control. A departmental purchase committee should be constituted at a suitable level to expedite purchases and quality control.

- Presently, hydrams are manufactured by private firms, some of which obtain supply orders beyond their manufacturing capacity without having requisite technical knowhow. Letters of intent should be issued to only those fulfilling norms fixed by the department in this respect. State public sector undertakings with workshop facilities can also be used to manufacture hydrams.

- Agricultural land under the command of a hydram project should be properly leveled so as to deliver water evenly. In Uttar

Pradesh, the Soil and Water Conservation Department has been engaged in leveling the fields under the hydram command.

- The backward hill areas need adequate extension support. Farmers should be persuaded to practice intensive farming to make use of the pump throughout the year. Appropriate application of fertilizer, pesticides, and suitable implements will go a long way toward producing high-yielding varieties.

- Land holdings in hill areas are small and the fields are terraced; irrigation potential is not fully utilized. In many places, land for the installation of hydrams is not available. Efforts should be made to consolidate land holdings.

- Traditional watermills in the hills have identical conditions to those required for the installation of hydrams. These watermills create problems for the installation and operation of the hydram, the former consuming more water for less output. With limited quantities of water supply, the hydram should get priority, keeping in view the larger interest of the village as a whole. The watermill should be redesigned with improved turbine-type mills.

- The supply channel, supply tank, pipeline, and hydram machine are prone to siltation during the rainy season. It is imperative to select a proper site. Iron gates and silting chambers should be provided where necessary.

- Most of the hydram units are set up far from the roadside in inaccessible places. In the event of leakages or any breakdown, arrangements for welding to plug the leakages are not possible due to unavailability of lightweight generator-cum-welding sets. Lightweight welding sets should be made available, which are easy to transport and convenient to handle.

Need for Further Techno-Economic Research

A great deal of techno-economic research and development work remains to be done on hydrams in a number of areas, including the following:

- Standardization of efficiency and specifications so that uniformity of high standards in mechanisms sensured, in view of the fact that the demand for hydrams is rapidly increasing.

- In order to further reduce the cost of irrigation per hectare, size of hydram, optimum number, and height of discharge point should be investigated.

- Hydram projects can be used for producing microhydro- power for meeting requirements of village industries.

- Reduction in the cost of civil works, which presently accounts for about 50 percent of the total expenditure, requires attention.

- Judicious use of pumped water is essential. The fields in the hills are terraced, which requires an effective water distribution system.
- The large size hydraulic machines (12"x6" and 8"x4") are too heavy. In some places, these may be very difficult to transport to the installation site. Further study is required to reduce weight.

List of **Manufacturers**

1. M/s. Saiba Engineering and Commercial Enterprise, 113/225, Swaroop Nagar, Kanpur
2. M/s. Inteco, 27/31 Badali, Delhi-2
3. Walia Engineering Co., Patel Marg, Ghaziabad (UP)
4. M/s. Premier Irrigation Equipment Ltd., 3 Netaji Subhash Road, Alipur, Calcutta
5. Shiva Industries, 77/156 Latouche Road, Kanpur

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APPENDIX - 1

TABLE SHOWING THE WATER-LIFTING CAPACITY IN 24 HOURS FOR VARIOUS SIZES OF HYDRAM AT VARIOUS LIFT MAGNIFICATION FACTORS AND AREA COVERED FOR VARIOUS DEPTH OF IRRIGATION

Lift Magnification	Sizes			2" x 1"	Size		4" x 2"	
	Gallons per day	Area covered per day (acres)			Gal. per day	Area covered per day (acres)		
		1"	2"	3"		1"	2"	3"
2	8256	0.37	0.18	0.12	34880	1.55	0.77	0.516
4	5808	0.26	0.13	0.086	24312	1.08	0.54	0.36
6	5808	0.20	0.1	0.066	19200	0.85	0.42	0.28
8	3504	0.16	0.08	0.053	14721	0.65	0.32	0.21
10	2880	0.13	0.06	0.04	12144	0.54	0.27	0.18
15	2112	0.09	0.045	0.03	8952	0.40	0.20	0.13
20	1392	0.06	0.03	0.02	5760	0.26	0.13	0.086
25	1200	0.05	0.025	0.02	5112	0.23	0.12	0.08
30	816	0.04	0.02	0.01	3504	0.15	0.075	0.03

Lift Magnification	Sizes		6" x 3"		Size	8" x 4"		
	Gallons per day		Area covered per day (acres)		Gal. per		Area covered per day (acres)	
	1"	2"	3"			1"	2"	3"
2	76800	3.41	1.71	1.14	132000	5.87	2.93	1.95
4	60792	2.70	1.35	0.90	111984	4.98	2.49	1.66
6	50544	2.25	1.122	0.75	96000	4.27	2.13	1.42
8	42240	1.88	0.94	0.63	79992	3.56	1.78	1.18
10	35520	1.58	0.79	0.53	67200	2.99	1.49	0.99
15	28152	1.25	0.62	0.42	51120	2.27	1.43	0.75
20	22392	1.0	0.5	0.33	41592	1.85	1.42	0.61
25	20492	0.91	0.45	0.30	35184	1.56	1.28	0.52
30	19200	0.85	0.42	0.28	27192	1.21	0.60	0.40

Lift Magnification	Sizes	12" x 6"		
	Gallons per day	Area covered per day (acres)		
		1"	2"	3"
2	320000	14.22	7.11	4.74
4	268800	11.96	5.97	3.98
6	217600	9.67	4.83	3.22
8	160000	7.11	3.55	2.37
10	134400	5.97	2.98	1.99
15	89600	3.98	1.99	1.32
20	57600	2.56	1.28	0.85
25	51200	2.28	1.14	0.76
30	44800	1.99	0.99	0.66

NOTE: If a battery of two or more hydrams be placed in parallel, the amount of water raised may almost be multiplied by the same number (excluding losses) with separate intake and common delivery pipeline.

PROSPECTS FOR COMMUNITY BIOGAS PLANTS

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INTRODUCTION

Biogas technology was initially propogated in India half-heartedly. With the onset of the oil crisis in the 1970s and the ensuing shortage of chemical fertilizers, the need for alternative sources of energy was made apparent. Biogas technology soon became the predominant source of renewable energy, particularly for the rural areas where the main feedstock--dung--is available in abundance. Although biogas plants were initially used only to produce cooking gas, technological improvements have made the fuel available for other end uses.

Despite great expectations of the national planners regarding biogas technology, only five percent of the families in India possess enough cattle to operate even the smallest biogas plant (Vidyarthi 1978). A number of studies have concluded that the technology is beyond the reach of poor families because of their lack of resources. It was observed that a small plant is not a viable unit for the operation of machines and engines. Technology also needs to be harnessed to provide the villages with energy for electricity, drinking water, flour milling, and village industries.

Why a Community Plant?

The community biogas plant (CBGP) emerged as a possible solution to these growing needs. A large-scale biogas plant, fueled by dung contributed by the cattle-owning families of the village, could provide cooking gas to the entire village as well as energy for the operation of a tube well, flour mill, or electric generator. These community plants would be owned and managed by the community itself, with technical and financial support from the government.

The community approach has been attempted in India for irrigation, agriculture, and small-scale industries, but the results are not encouraging. Neverthelesss, the idea of a community biogas plant was applied in the absence of a better alternative.

Early Attempts

The first experiment was conducted by the Planning Research and Action Division (PRAD) of the State Planning Institute of U.P. in 1978, at Fateh Singh Ka Purwa village in Etawah District (U.P.). The project installed two biogas plants, with capacities of 30 and 40 m^3, to provide street lighting and energy for a tubewell used for irrigation and drinking water, as well as to supply cooking gas and electricity to all 24 families of the village. The project, though it received considerable publicity as the first of its type, could not sustain itself due to misprojections of dung availability, reluctance of the villagers to provide dung, village factionalism, and poor management (Bahadur and Agrawal 1979).

About the same time, a similar attempt was made in the village of Kedumunja in Karimnagar District (A.P.) by the Sircilla Electric Cooperative Society. A plant with a capacity of 128 m^3 was installed to provide cooking gas to 60 families, and operate the pumpsets. The plant required dung from 300 cattle. This project also had inadequate supplies of dung, which then had to be purchased. The community failed to show interest in the project as cooking was not a priority need (Moulik 1982).

Another widely publicized experiment was conducted by the Application of Science and Technology to Rural Areas (ASTRA) unit of the Indian Institute of Sciences in the village of Pura. The project intended to meet the entire energy demand of the village with various renewable sources of energy, of which a large-scale biogas plant was one. The project is reported to be successful (Reddy and Subramaniam 1979), but the role of the community biogas plant is never mentioned.

In the early stage of the community biogas program, a large- scale biogas plant was installed in the staff colony of the Kurukshetra Sugar Mill. The gas was used for cooking purposes by 18 families of the colony. The plant ended operation within six months, due to an insufficient supply of dung and disputes over the timing of the gas supply.

The village of Masudpur near Delhi was selected for the demonstration of various new energy technologies. A large-scale biogas plant was commissioned and is still in operation. The project has been successful for several reasons: the dung is purchased; spent slurry is sold to the Horticulture Department; the beneficiaries are not directly involved in the management of the project; and the villagers, close to the capital city, are used to LPG supply.

An experimental 140 cubic meter-capacity plant was built in 1981 by the Vimla Gram Seva Samaj Trust in the village of Kubadthal in Ahmedabad District. It was designed to meet the cooking fuel requirements of 123 families. This project also faced a number of organizational, sociopolitical, and economic problems (Moulik 1984).

Present Status

The Department of Science and Technology (DST), formerly the apex body of the central government, fully aware of the results of these experiments, decided to conduct a few more trials under different agroclimatic and sociocultural settings. The Department assigned new projects to PRAD and the Khadi and Village Industries Commission (KVIC), using different drumless (PRAD) and drum (KVIC) designs.

The Department expected the future strategy of CBGP construction would be decided after examining the outcome of these trials, but neither institution completed the construction work within the stipulated time. The Department of Non-Conventional Energy Sources (DNES), newly established solely for these activities, commenced its policy of providing a 100 percent subsidy for community and institutional biogas plants.

The community biogas plants constructed by PRAD and KVIC met with the same fate as the initial experiments. The plants installed by PRAD were beset by technical problems (Agrawal 1983) because a new design was being tested. The plants installed by KVIC had many socioeconomic and administrative problems (Murthy 1983).

Under the Community and Institutional Biogas Plants Demonstration Scheme initiated by DST in 1981-82 and later managed by DNES, 34 community and institutional biogas plants were sanctioned to various states, with a maximum number of 12 given to Uttar Pradesh. The experiments cited above were conducted before 1981-82, with sufficient experience gathered to formulate sound policy. In recognition of the problems faced in involving the community in the operation and management of the plants, the construction of institutional plants was encouraged. These plants are mainly located in agricultural universities, dairy and animal husbandry farms, and other institutions where feeding materials and management facilities are available. In the institutional plants, technical problems can be isolated from the problems faced by the community biogas system, such as distribution, management, and contribution of dung.

By the end of 1984-85, DNES had sanctioned 240 community and institutional biogas plants, of which 60 were reported to be commissioned (DNES 1984). Among the 18 states where projects have been sanctioned, Assam and Himachal Pradesh are the only two hill states, although Uttar Pradesh has considerable hill area. In Assam, one community biogas plant was sanctioned in 1981-82 and is now operating in Silchar. In Himachal Pradesh, one plant was sanctioned and is operating in Sundernagar. In Uttar Pradesh, out of 15 completed plants, five are located in the hill districts of Nainital and Dehradun. However, the plants are installed in the foothills and thus cannot provide substantial information regarding the problems that may be encountered at high altitudes.

Thus, at present, only two CBGPs are available for gaining practical experience in hill areas. However, these are both institutional plants and the village communities are not directly involved in project operation. The two projects could provide important information regarding the applicability of biogas technology in hill areas, but no document on these projects is yet available.

In the absence of any data on CBGPs in hill regions, the author focused on the family biogas plant experiences in hill areas. There are 6 family biogas plants in Nagaland, 2172 in Himachal Pradesh, and 106 in Jammu and Kashmir. Most of these plants have been installed in foothills and valleys. Although separate figures for the hill districts of U.P. are not available, many biogas plants have been installed in the foothills, and a few are operating at altitudes of up to 5000 feet. Valuable information has been collected from these plants and was used as the basis for this paper.

FEASIBILITY OF THE SYSTEM

Technological Factors

Design. The KVIC design for large-scale plants is considered to be the most successful. The drumless design developed by PRAD is also successful but its large-size design has not yet been released. The Ganesh model, a polythene sheet-lined digester made from an angle iron frame, is also accepted by DNES but its large-scale design is not available. Similarly, the prefabricated *ferro* cement digester has only been tested for capacities of two to six m^3. Thus, the KVIC design is used in most of the plants.

The major difficulty in operation of the KVIC model in the hill region is heat loss through its metal gas holder. The holder remains exposed and thus is susceptible to temperature variations, resulting in reduced gas production during winter (Prasad and Sathyanarayan 1979). A second limitation of the design is that an underground digester requires substantial digging which is often impossible. Transportation of the steel gas holder is another problem associated with the KVIC design.

Accordingly, the Janata design is more suitable for the hill regions because the heat losses are smaller and construction materials can be obtained locally. This design has been incorporated in the large-scale biogas plants in the hills of Nepal, China, and Korea, and in family biogas plants in the hill states of India.

Soil. Soil conditions are important for the construction of the biogas plants. Sandy soil is not recommended for the KVIC model (KVIC 1975), and rocky soil may restrict construction of an underground digester. Since the hill regions mainly consist of sandy and rocky soil, additional engineering inputs will substantially increase costs.

Water table and water requirements. To facilitate the construction of an underground digester, a site should be chosen where the water table is low. The water table in the hills may not pose any problem since it is quite low at high altitudes. However, an almost equal amount of water is required to be mixed with the dung before it can be used as biogas fuel. For a 30 cubic meter-capacity plant, about 675 liters of water would be required on a daily basis. In the hill regions, where even the collection of enough water for drinking purposes is difficult, the availability of water in such large quantities is highly doubtful. Even if a water source is available near the site, transporting the water to the plant will be a highly labor-intensive job (UNESCO 1984). Thus, water may be a limiting factor in the hill regions (Santerre and Smith 1981) since reducing the water to dung ratio can decrease gas production considerably.

Feedstock. Cattle dung is the most common feedstock used in India for the generation of biogas. A 30 cubic meter-capacity plant would require 9.1 quintals of dung daily (NAS 1977), which could be produced by 90 adult cattle at a rate of 10 kg per day (NRDI 1977). This figure is based on the data from the plains of northern India, where cattle have higher body weight than in the hill regions. The smaller breed of cattle available in the hill region means that at least double the current number

Table 1: Per Family and Per Person Cattle Ratio in U.P. Hills

District	Population	Families	Cattle	Man/ Cattle ratio	Family/ Cattle ratio	Sheep/ goat	Man/ sheep ratio	Family/ sheep ratio
Dehradun	688000	137600	45553	1:0.06	1:0.34	133044	1:0.19	1:0.96
P. Garhwal	599000	119800	64513	1:0.10	1:0.53	232001	1:0.38	1:1.93
T. Garhwal	428000	85600	101982	1:0.23	1:1.42	134565	1:0.31	1:1.57
Uttar Kashi	165000	33000	32587	1:0.19	1:0.98	173600	1:1.05	1.5.26
Chamoli	318000	63600	57202	1:0.18	1:0.90	202806	1:0.63	1:3.18
Pithoragarh	463000	92600	95810	1:0.20	1:1.03	216785	1:0.46	1:2.34
Almora	711000	142200	151568	1:0.21	1:1.06	204346	1:0.28	1:1.43
Nainital	952000	190400	149443	1:0.15	1:0.78	56643	1:0.06	1:0.30
Region	4324000	864800	698658	1:0.16	1:0.80	1353790	1:0.31	1:1.56
U.P.	98200000	19640000	13964751	1:0.14	1:0.20	10521127	1:0.10	1:0.59

Source: Livestock data : Livestock Census, Govt. of U. P., 1978.
Population data : Projections in Statistical Dairy, Govt. of U. P., 1978.

of cattle will be needed to run a biogas plant in this area. The author's studies revealed that the total amount of dung produced in a village is never available for the plant because the villagers are reluctant to contribute dung, as it is difficult to collect during the grazing period, and families retain a portion of the dung for plastering the floor and walls (Agrawal 1980). Thus, the number of cattle needed (estimated on the basis of per day dung production) will be misleading and insufficient.

An alternate method of estimating the number of cattle required in a community for the operation of a CBGP is to consider the man-cattle ratio, which should ideally be 1:0.5 (PRAD 1983). During a search for a suitable village in the valley area of Dehradun District and the Terai area of Nainital District, the author could not identify a single village in which the ideal man-cattle ratio was maintained. The village finally selected in the valley area had a 1:0.6 ratio; the Terai village selected had a 1:0.8 ratio (Agrawal 1980). The situation in the village at high altitudes can thus be inferred.(Table 1)

The number of family biogas plants in the hill regions will be limited by the small cattle population and the low dung supplies. Nonetheless, a number of families which have sufficient cattle for the operation of a four cubic meter-capacity plant can be identified.

There are a number of alternative feedstocks, such as *ipomea*, *salvinia*, water hyacinths, banana stems, industrial effluents and waste; canteen, kitchen, and agricultural wastes; and night soil, sludge, and city garbage. Experimental plants based on a few of these, such as sludge, night soil, and water hyacinths, have been built but of these only night soil is available in the hill region. Human excreta can be used as an additional feedstock, but the latrine system is not common in the hill regions and the gas produced from it is not socially acceptable.

In the following table, the average gas production from various feedstocks is presented, indicating that both poultry and sheep dung produce gas in amounts comparable to cow dung. Forage leaves available in the hills can also be used as an alternative feedstock. In light of the scarcity of cow dung in the hill region, the use of alternative feedstocks may increase the promise of biogas technology in the hills. However, a change in the design of the plant or pretreatment of the slurry may be required.

Table 2: Yield of Biogas From Various Waste Materials

Raw materials	Biogas production per unit weight of Dry Solids	
	ft^3/lb	m^3/kg
1. Cow dung	5.3	0.33
2. Cattle manure	3.6 - 8.0	0.23 - 0.50
3. Poultry manure	8.9	0.56
4. Sheep manure	5.9 - 9.7	0.37 - 0.61
5. Forage leaves	8.0	0.50
6. Night soil	6.0	0.38
7. Elephant grass	4.8	0.30
8. Paddy straw	2.1	0.13
9. Farm waste	3.9	0.24

Temperature. Temperature plays a crucial role in the anaerobic decomposition of biomass because methane-producing bacteria are particularly sensitive to temperature. Below the 10° to 15°C range, the digestion process is very slow, although it can function down to 5°C (Meynell 1976). The optimal range is from 30° to 35°C for the mesophilic bacteria to flourish. It is possible to achieve a faster digestion in the 40° to 55°C range, in which the thermophilic bacteria operate. The temperature should be maintained as constant as is possible and not vary by more than one or two degrees centigrade within a 24-hour period. In the hill regions, the low temperatures during most of the year and fluctuations of daily temperature are bound to present major problems for the functioning of the biogas plant.

In the Khadi Commission Biogas Research Centre, 2.4 m^3 of gas was produced from 5.4 m^3 of cattle dung every day at a digestion temperature of 25°C. When the temperature was raised to 28.3°C, the gas production increased to 6.3 m^3/day.

At the Indian Agricultural Research Institute, it was observed that gas production was reduced by almost 50 percent during the winter months when the mean monthly temperature dropped to 2.7°C in January.

Experiments in China proved that within the 15° to 35°C temperature range, total gas yields per ton of raw material were almost equal. When the temperature is lower, the digestion is slow, necessitating an increase in the detention time and plant size, and increasing the cost of the plant. Research findings, however, do not match the observations of visiting scientists. An FAO team reported that a decrease in gas production during winter was observed in all regions (FAO 1987). Another report (DGTZ 1981) reports that in Shanyang, in the Idaoning Province, the average temperature ranges from 0° to 13°C, which is unsuitable for biogas production.

It is reported that the gas production per kg of input material at 20°C is about 90 percent of that achieved at 30°C. At 20°C the yield is about 66 percent, at 15°C it is about 50 percent, and at 10°C the yield is down to about 40 percent of what would have been produced at 30°C (PRAD 1980). Sharma and Panwar (1985) found that higher average daily temperatures result in higher peak relative gas production. When the temperature decreases from 35.58°C to 24.55°C, gas production decreases by 44.8 percent; when the temperature further drops by 12.11°C, the total reduction in gas production is 77.39 percent.

Though individual biogas plants are operating at altitudes up to 5000 feet, personal communication with the plant owners revealed that gas production dropped by 50 percent during winter, despite precautions taken such as using hot water, cattle urine, and urea fertilizer, and covering the plant with paddy straw.

Systematic investigations of digester/slurry heating have been carried out in China, Korea, India, and Japan. On the basis of these studies, it is recommended that the plants be insulated and the slurry be heated. A feedback principle was applied in India, in which part of the gas produced is used for heating the slurry. In China, wasted heat from gas-operated engines is used to maintain the slurry temperature. Experiments using solar heat have also been successful in India (DNES 1984).

At the Indian Institute of Science, Bangalore, heat loss from the top of the gas holder has been minimized by adding a transparent cover. In Korea, a heating and mixing device known as a bubble gun has been developed which generates intermittent gas bubbles inside a mildsteel tube.

The temperature variation in the hill region is shown in Maps 1 and 2. It is evident that unless the precautions mentioned above are applied, the successful operation of a biogas plant will be a remote possibility.

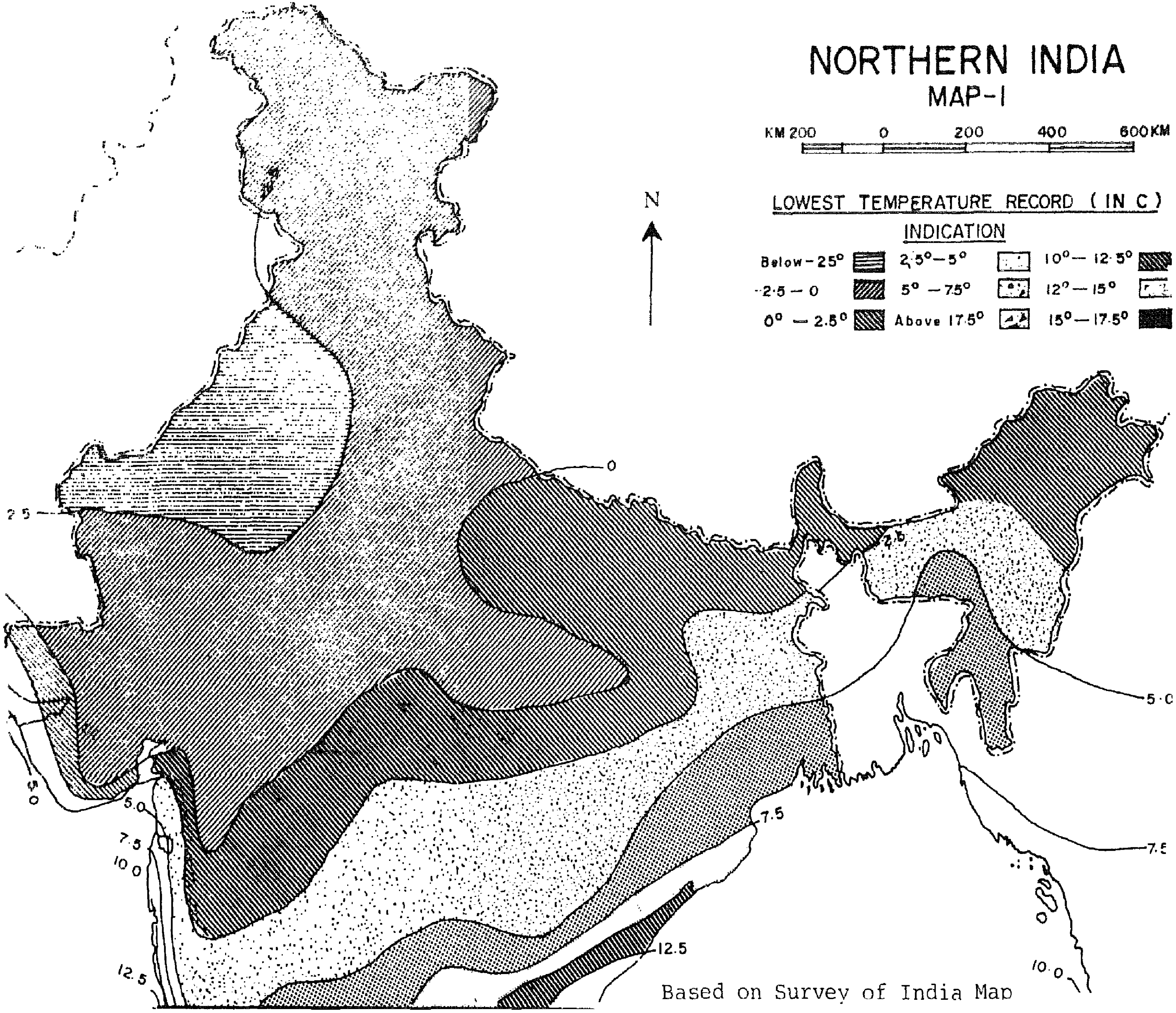
Due to low and varying temperatures, and insufficient supplies of dung, biogas plants in the hill region may fail to meet energy demands of the community during a large portion of the year. If a plant cannot function during winter when fuel demand is highest, the villagers will lose enthusiasm for the plant and will not supply dung, ultimately terminating the project (Bahadur and Agrawal 1979).

Spatial pattern. Sufficient space is required for the construction of a large-scale biogas plant, the digging of pits for the accumulation of spent slurry, and the installation of the required machinery. A minimum of 150 m^2 of land is acquired in Uttar Pradesh for each plant. Agricultural land cannot be used for the construction of the plant. Common land is rapidly shrinking in the hill area, and whatever common land is available is used as pasture land. The prevalence of fodder shortages will make the villagers unlikely to forsake their pasture land to build a biogas plant. This problem was faced by the author during an intensive search for a suitable site for a community biogas plant in Himachal Pradesh. Out of 16 villages suggested by the state, common land of sufficient size was available only in one village (Agrawal 1980). However, land may not be a limiting factor in the valleys and foothills.

Even if sufficient land is available, the laying of a gas distribution system in a hill village would be an arduous task. A minimum gas pressure is required at every burner point, which is maintained by providing a constant slope in the pipeline, starting from the plant and ending at the last house of the village. In the hill villages, where houses are dispersed and constructed at different ground levels, the gas supply could not be managed easily even by providing boosters or gas accumulators.

Social Factors

In the adoption of any technology, several socioeconomic and cultural factors play a significant role. Evaluation studies conducted by research teams have pointed out the association of economic status, population, education, and landholding (Moulik and Shrivastava 1976; Agrawal 1979; UNESCO 1984), family size (Moulik and Shrivastava 1976; UNESCO 1984), and age (UNESCO 1984) with the adoption of biogas technology. The study carried out by Smith et al (1980) in Nepal indicated that a higher percentage of those who adopted the technology had bigger families, more land, more livestock, and greater leadership



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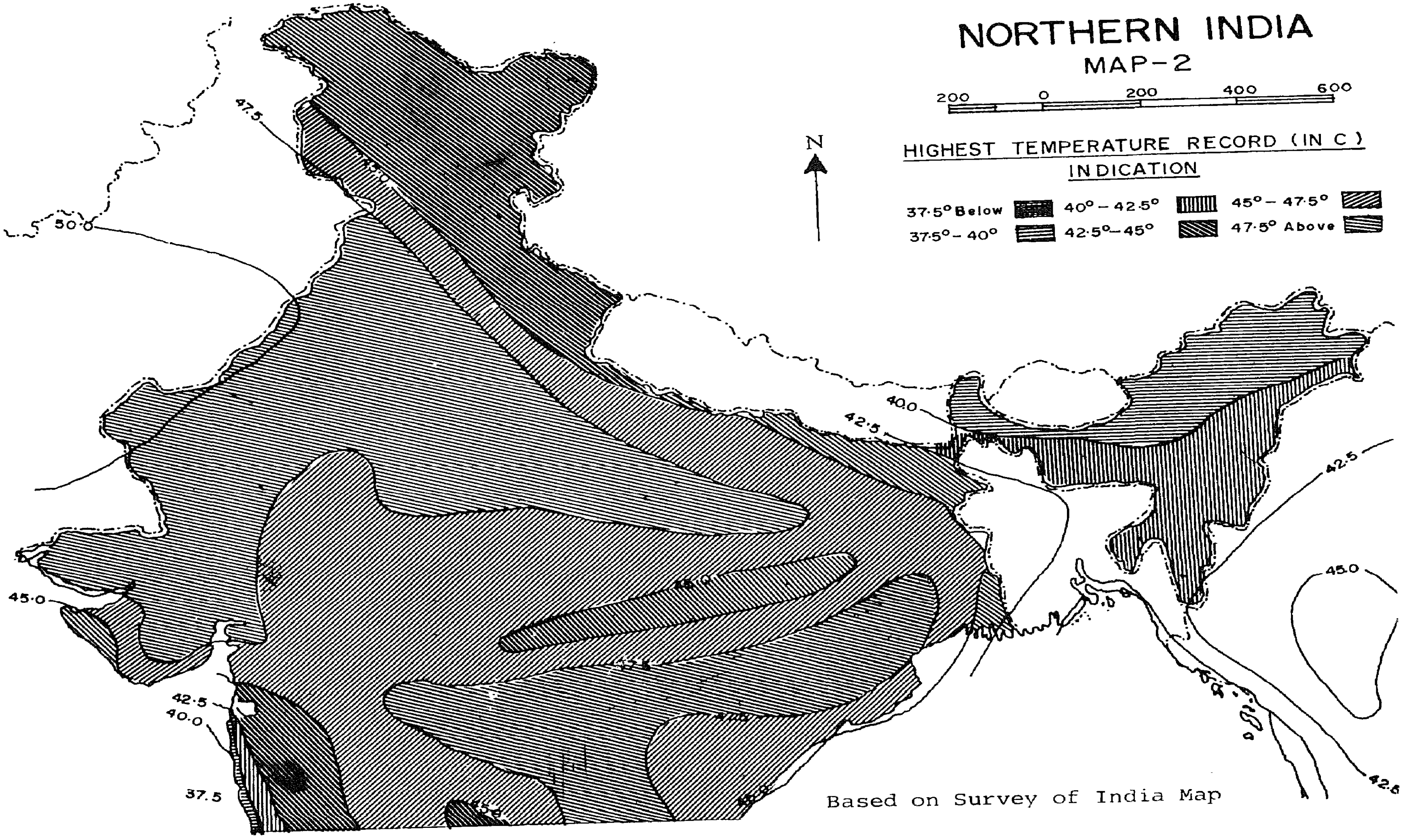

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responsibilities. Limiting factors include: high initial cost (Briscoe 1977; Agrawal 1979; Moulik 1982; Chun 1984; Skulbhram 1984), problems in handling waste and spent slurry (Chun 1984), symbolic factors (Agrawal 1979; Chun 1984; Skulbhram 1984), lack of space (Agrawal 1979), and breakdowns (Agrawal 1979; Moulik 1982; Chun 1984) Additional socioeconomic issues are discussed below.

End-use patterns. The basic objective of the CBGP is to meet the cooking and lighting needs of the villagers. Other objectives, such as providing facilities for drinking water, street lighting, irrigation, and flour milling, are decided on the basis of local needs. The gas budget and size of the plant are estimated, taking into account the energy priorities and requirements of the community. However, the shortage of dung to fuel the plant makes it unable to provide sufficient gas for all these activities. As such, in most cases only the cooking requirement is being met (NEDA 1985). In projects where gas for other activities is being provided, this is done only occasionally. Nonetheless, prior to installation, the villagers are assured of the availability of gas for these facilities. As a consequence of false assurances, the villagers' confidence in the system is shaken, expressed by their non-cooperation (Bahadur and Agrawal 1979).

The energy priorities of the hill community are mainly cooking fuel, drinking water, lighting for domestic purposes, and irrigation for the agricultural sector (Agrawal 1980). Villagers will forgo electric lighting for a drinking water facility (Agrawal 1980). In studies of several rural villages in Almora, Nainital (U.P.) and Kangra (H.P.) Districts, it was estimated that the per person annual requirement of cooking fuel is 7.2 x 10^5 kcal.

In a study conducted by NCAER (1981), per family annual energy requirements for cooking and lighting in the hills was about 88 x 10^5 kcal., or 993 m^3. biogas. For a village of 30 families, under ideal gas production conditions, a 82 cubic meter-capacity CBGP would be sufficient. For the operation of the plant, 10.3 quintals of dung would be needed daily, requiring at least 205 cattle, or a person-cattle ratio of 1:1.5--a remote possibility as seen in Table 1.

Thus, even if optimal gas production is assumed, a community biogas plant may not even be able to meet the cooking needs of the community.

Food habits. The rate of cooking fuel consumption is higher in the hill regions than in the plains (NCAER 9181). Free access to fuelwood, use of traditional stoves, present food habits and cooking practices all cause higher fuel consumption. With the exception of rice, most cooking by the hill population consumes a lot of fuel and requires heat of low thermal value. Use of the pressure cooker is not common in the rural hills. Continuation of these practices under the limited gas supply of a biogas plant would lead to its rejection (UNICEF 1984). Changes in food habits and cooking practices to conserve energy will increase the chances of biogas technology being adopted.

Community cohesion. A primary component of the community project is the cohesiveness and community feeling among the villagers. Indian society is divided both horizontally and vertically on the basis of caste, class, and kinship. Despite these divisions, a joint venture can be successful if the members have a strong sense of belonging to their village. Community unity surfaces only when the community considers issues to be important.

Whether a community will attach the necessary importance to a CBGP is doubtful, as shown by the following statement:

"Sahib, when two brothers cannot live jointly, cannot share a property, how can a community share a plant?" Dharam Singh (Dharmuchak, Dehradun)

Similar reactions were common in both the hills and the plains. The villagers were convinced of the advantages of biogas technology but most were reluctant to have a community plant.

"*If you ask me, I will go for an individual plant for my family, but sharing a plant with other people will deteriorate the village life.*" Mohan Singh (Jagaria, H.P.)

The respondent believed that any community project would not only fail but would create conflict and tension within the village. There is no empirical evidence to substantiate this claim, but most villagers expressed similar doubts.

Village factionalism is a strong barrier to the cooperative spirit required for a communal scheme to succeed. Inter-factional rivalries often arise during the later stages of the project if one faction achieves prominence through the project, even if the benefits are distributed equally and with mutual consent (Bahadur and Agrawal 1979).
The reasons for conflict and dispute as observed in the existing projects are mainly related to:

- The social status of the president of the village committee belonging to one faction, thus making other factions disgruntled

- Families who do not contribute dung or land, yet share equal benefits

- A lack of cooking gas supplies for large families, prompting them to continue their dependency on dung-cake, and reduce their contribution of dung. (Other families may follow their example even if their needs are being satisfied, starting a vicious cycle.)

Village leadership. The identification of formal and informal village leadership and their attitude toward the project is crucial for the project's success. The more traditional hill communities do not distinguish between formal and informal leadership. The informal leadership is comprised of different people for various spheres of life. The village leadership in the hill regions have not lost social and political values like their counterparts in the plains. This style of leadership facilitates the creation of a community system.

Level of cooperation. Social values, customs, and traditions--the major tools of social control--are not as disrupted in the hill communities as in the villages of the plains. Interactions between various sections of the community in the hill regions are stronger, and despite ritualistic barriers, caste and non-caste Hindus share many common values. The hardship of hill life has prompted a greater sense of cooperation. It is common to see people in the hill regions carrying boulders or slate on their heads to distant villages to help with house construction. Cooperation is also seen in several labor-intensive agricultural operations. This spirit could be harnessed for a community biogas plant, enabling the hill regions to avoid the factionalism seen in the plains.

Administrative systems. In the case of India's first CBGP, it was proposed that the system be managed by an elected village committee with technical support from PRAD. A similar approach has been adopted in the other CBGSs (NEDA 1985). The institutional plants are managed by the institution itself. There may be a better administrative system, but thus far no other method has been adopted in a community biogas plant.

This administrative system has not been very successful, as shown by the fact that seven years after its completion, the village committee of Fateh Singh Ka Purwa has failed to take responsibility for the project. A study of several CBGPs in U.P. revealed similar situations in which plants are being managed by government agencies (NEDA 1985).

In the context of the hill regions, this administrative system appears even more difficult. The various socioeconomic and technical problems posed by a CBGP can be solved only if, before the project is initiated, the village committee is aware of the problems and if the community is prepared to share the responsibilities (Morseat et al 1984).

Alternatively, voluntary organizations could be used for plant administration. In the CBGP at Kashipur, the services of the Gandhi Ashram were sought and results were very encouraging. In a project at Bulandshahar,a local voluntary organization was involved at the initial stage of implementation which helped to create a favorable atmosphere in the village.

A third alternative for the administrative system is to involve private entrepreneurs who can purchase the dung and provide it on a commercial basis. To safeguard the interests of the poor families, restrictions on the rate of various services provided by the entrepreneurs can be fixed by the government through project subsidies. Private firms have already emerged, specifically created for the construction of large-scale plants, which are then responsible for operation over a specified period of time. These contractors are prepared to run the project on a commercial basis if the project is subsidized (personal communication). The major difficulty of the private sector approach is once again the availability of dung. For many socioeconomic reasons, the villagers are reluctant to sell the dung (Agrawal 1981). This attitude is changing in villages located near urban areas, but attempts in remote villages to purchase dung have failed. This system is being experimented with in the NEDA-run projects. However, the author observed during field visits that sufficient dung was not available and the villagers would not purchase the slurry, which then accumulated.

Lastly, the CBGP could be run by a central agency at the state level. The agency or board in charge of promoting new energy systems could be responsible for the continuous management of the plants in a commercial manner similar to the electricity boards.

In the hill villages, of these four administrative options, a government agency would be able to manage a CBGP plant most successfully. Few volunteer organizations are active in the area who could share the responsibility.

Distribution systems. Expectations from a community project vary among different groups depending on their priorities. However, whereas an affluent family may value lighting over cooking gas because they can afford other fuel sources, a poor family will give more weight to cooking gas and will resist any project which threatens its availability. A compromise among the various groups is essential for the success of any community project. This task is made more difficult when the benefits are limited.

Maintaining the supply of cooking gas is essential because the plant requires dung previously used as fuel. Thus, the dung supply will cease if cooking gas is not available. However, this problem may not arise in the hill village where dung is not commonly used as fuel. This provides a possibility of utilizing gas for non-cooking activities.

The energy survey conducted by the author in the hill regions of U.P. revealed the following energy priorities, based on first, second, and third choices given by respondents:

Table 3: Energy Priorities in the U.P. Hills

Activities	weightage score
Drinking water	1170
Cooking	1045
Threshing	980
Heating	850
Lighting	850
Flour milling	530
Oil extraction	440

Irrigation, though a priority need, was not included in the survey because of the limited possibility that a biogas plant could provide sufficient energy for it. In the foothills and valleys, an irrigation facility can be run by a dual fuel (diesel gas) engine. The problems with this engine are almost the same as those encountered in the operation of a diesel engine.

Another distributional problem is timing the energy supply to the villagers, whose demands for energy vary with the occupation and mode of living of the family. Agricultural families require cooking gas on a different schedule than a family involved in services. The amount of energy demanded is directly related to family size. Economic status is also a determinant of energy demand. These variations are present in every community posing real problems for designing a distribution system. These can be overcome only by strengthening the cohesiveness and mutual understanding in the community.

Economic and Financial Factors

The economic viability of both family

and community biogas plants may be estimated using various techniques. The most popular among these is social cost-benefit analysis. In the initial stages, this analysis helps the decision-makers fix the subsidy rate and encourage banking institutions to finance the plants. Along with cost-benefit analysis, the internal rate of return, net present value, and pay back period are calculated (Bhatia 1976; Barnett 1976; ICAR 1976; Sanghi 1976b; Verma 1976). However, in evaluating the benefits of methane generation in a developing country, the possible sources of the gas should be identified and only those benefits should be included which are likely to directly accrue from the project (NAS 1977).

In recognition of the limitations of this approach, actual consumption of fuel by the people and services to be rendered by the plant was used rather than estimating benefits on the basis of coal and kerosene replacement values (Maulik 1982; Bahadur and Agrawal 1979; Bhatia 1977; Briscoe 1977; Prasad et al 1974). Even in this form of analysis, the economics is worked out by examining only a few dimensions of the problem. In addition to the technical and economic dimensions, consideration should be given to the social and environmental impacts (Barnett 1976). The Fuel Linked Energy Resources and Technologies. FLERT approach has been suggested for evaluating small-scale rural energy technologies (Smith and Santerre 1980).

The economic analyses carried out by Moulik (1982) for several different plant sizes reveal that all sizes of plants,

Table 4: Pattern of Central Subsidy for Biogas Plants (in Rupees)

Size of Plant (cum.)	For North-Eastern Region States, Sikkim and notified hilly areas and desert districts.	For other areas		
		For Scheduled Tribes/small marginal farmers and landless labour	For Scheduled Castes	For others
2	2940	2350	2350	1560
3	3660	2860	2860	1900
4	4390	3220	3220	2140
6	5350	3920	-	2610
8	6460	4640	-	3100
10	8080	5540	-	3700
15	11440	8150	-	5430
20	15260	10960	-	7300
25	17640	12280	-	8190

except 60 cubic feet are economically viable. For the community biogas plants, a large-scale plant is more economical than a family plant (Moulik 1982; Verma 1981; Bhatia 1980; Ghate 1979; Bahadur and Agrawal 1979; Reddy and Subramanian 1979). A number of authors have also established the economic viability of CBGPs in India, Korea, China, and Thailand. Reduction in per unit costs by increasing the plant size is presented in Figure 1.

However, controversy continues about the benefits of the system. Usually the manure value of the slurry, savings in terms of fuelwood, kerosene and dungcake, in addition to financial returns from commercial activities, are considered direct benefits. These estimations are meaningful only when supported by actual field data. From this point of view, the CBGP system will remain economically viable in the hill region.

The DNES has made provisions for subsidizing construction costs. The rates of subsidy for different sizes and categories of plants are shown below. The table reveals that higher subsidies are allowed in the northeastern states, Sikkim, notified hill areas, and desert districts. The subsidy rates are given for plants to a maximum capacity of 25 m^3 because an individual family is not expected to want anything larger.

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The total cost of the CBGP is borne by the government, including construction of the plant and distribution system, purchasing machinery and equipment, and contributing operational expenditures for three years. A CBGP project with a capacity of 85 m^3 costs from Rs. 217,000 and Rs. 286,000 (NEDA 1985). The community contributes its share by providing free land. Cooking gas is provided only to families which agree to pay for the service. In the hills, the project costs will be higher because of additional transportation needs and changes in the plant design. How long projects of such high initial cost can be fully subsidized is an important policy question.

A recent development is the escalation of construction costs of large-scale plants. The total cost of a 60 cubic meter-capacity plant, about Rs. 100,000 in 1977, is now at least Rs. 400,000 (NEDA 1985). The cost-benefit ratio is not computed by any non-official agency based on current construction costs. On the other hand, though an increase in the price of fuelwood and kerosene is observed, the increase is not at par. As a result of this trend, the gap between costs and benefits will certainly become narrower. In addition, the geographical limitations of the hill area will escalate construction costs, further shrinking the gap between cost and benefits.

When estimating average gas production, decreasing gas yields caused by temperature variations should also be

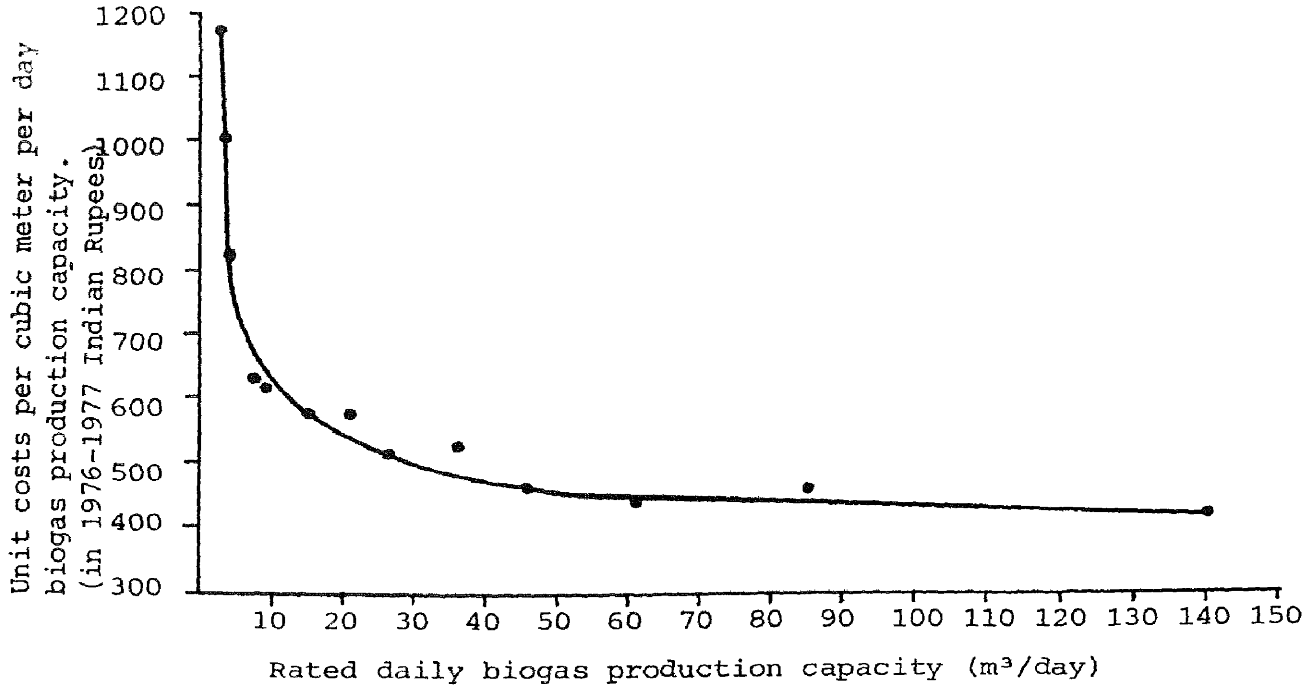

Figure: 1 Economics of Scale in anaerobic digesters. Comparative initial costs of floating dome anaerobic digesters, per cubic meter of installed daily biogas production capacity. (Adapted from Ghate 1979) taken into account, as should the increased costs of gas distribution caused by the dispersed spatial pattern of the village.

The financial aspects of the project depend mainly on cash returns from the project. As mentioned earlier, with the limited supply of dung and decreased gas production during the winter, a CBGP located in the hill regions will not be able to fully meet the cooking gas requirement. Based on past experiences, it can be safely said that in most areas, people will be reluctant to pay any amount for the services provided by a CPBG. The shortage of financial returns will place a continuous burden on the managing agency. It is thus essential to analyze potential alternative end uses of gas.

For a self-sustained CBGP system, provision of cooking gas is not an advisable activity; the best financial returns can be expected when the gas is converted into electricity which can be utilized for domestic and street lighting, and operating village-level industries (Agrawal 1984).

Environmental Factors

Fuelwood constitutes a major share of the cooking fuel consumption in the hill regions (NCAER 1981). With the current rate of population growth, fuelwood demand is increasing and, as a result, deforestation has reached an alarming stage. The ecosystem is badly affected, the upland areas are subjected to destructive erosion, and the resulting sediment causes rapid filling of the reservoirs and flooding downstream. Use of fuelwood is also a major source of air pollution which adversely affects human health.

The environmental deterioration can be checked to a certain extent by introducing biogas technology. Annual per household consumption of fuelwood in the hill region is estimated to be 1103 kg compared to 466 kg in the plains (NCAER 1981). As shown in Table 1, in 1978 the hill districts of Uttar Pradesh possessed 698,000 cattle and 1,354,000 goats and sheep. Using an average dung production of 5 kg for cattle and 1.5 kg for goats and sheep, 791 x 10^6 m^3 of gas could be produced annually from the dung, replacing 800 x 10^6 kg of fuelwood. Since the thermal efficiency of biogas is 60 percent, compared to 17.3 percent for firewood, effective heat from biogas will be much higher. If the other biomass materials listed in Table 2 are used, available gas can easily replace the use of fuelwood.

However, in light of socioeconomic and technological constraints, even if fuelwood consumption could not be completely replaced by biogas, individual family plants would be useful in the hills as additional energy sources.

CONCLUSIONS

Serious environmental degradation and scarcity of fuelwood make the search for alternative sources of renewable energy an important priority. Biogas has emerged as a viable alternative source of energy. However, its applicability in the hill regions depends on various technological, socioeconomic, and institutional factors.

The hill regions have extremely diverse

topographical conditions which make any generalization misleading. The technological constraints discussed earlier may not pose such serious problems in the foothills and valleys as in the hills. It is apparent that current biogas technology, especially community biogas systems, has a limited chance for success in the hills.

The most serious limitation of the technology is low gas production during winters. Among the existing designs, the drumless biogas plant has an edge over the KVIC design, although its performance is still limited by temperature fluctuations. The use of fiberglass in place of steel has successfully solved this problem in Korea (UNESCO 1984). India has attempted to solve this problem by insulating the plant and using a solar heater (DNES 1984). These and other possible technical solutions may control the fermentation of the slurry at low temperatures.

Inadequate water supply is another constraint requiring immediate attention. In Thailand, one-fourth to one-fifth of the biogas non-users had water supply problems because they lived in high-lands far away from a water source, and faced acute water shortages during part of the year (UNESCO 1984). The plants must be redesigned to use less dung, and hence less water, in order to be applicable in the hill regions. In addition, the high water table in the valleys and foothills may necessitate additional engineering inputs.

Inadequate dung supply may be compensated by linking the system to latrines. This will require additional effort to induce people to use the latrines. It will also require a change in social values before using gas produced from human excreta is widely accepted. This problem was overcome in Korea and Thailand by an educational program (UNESCO 1984). The goat and sheep dung available in the hills can compensate for the shortage of cattle dung. The hill region has an abundant supply of pine needles and other biomass sources, which could also be used for the generation of gas.

The spatial pattern of the hill villages may not pose any problem for the family biogas plants, but it will be a limiting factor for the larger community biogas plants. Gas distribution will also be difficult in the hill regions.

The main socioeconomic factors restricting the adoption of biogas technology are high initial cost, problems in handling waste and spent slurry, high fuel consumption, insufficient technical knowledge, and the lack of proper institutional facilities. In addition, a CBGP requires mutually agreed upon gas budget decisions and changes in traditional cooking practices. The sociocultural environment in the hills is more conducive to CBGP, although individuals may be reluctant to accept a joint venture.

The system will be more socially and economically acceptable if the CBGP becomes a nucleus of the industrialization of the village. A major part of gas production should be used for the operation of cottage and small-scale industries. Any project that generates employment opportunities will be welcomed by the people, especially in the hill region where job opportunities are scarce.

Other social constraints can be minimized by pre-project educational programs. A favorable atmosphere can be created in a village by discussing the project with the villagers and convincing them of the project's merits. It may be a time-consuming process but it is essential for success.

In conclusion, individual biogas plants may have limited potential in the hill regions, but it would be fatal to impose CBGP systems in the hills at the present premature stage.

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Section 2 : ENERGY AND PEOPLE

LOCAL PARTICIPATION IN RURAL ENERGY DEVELOPMENT PROGRAMMES

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INTRODUCTION

A number of development programs aim to introduce new methods and technologies for better utilization of resources to meet the energy needs of the rural population. Being linked to practically all sectors of a village economy, energy programs have special importance in the process of rural development, and the active participation of villagers is sought for their successful implementation. The term "people's participation", however, has become a cliche' for indicating any kind of local involvement, irrespective of its nature or contribution to the welfare of local inhabitants. It is no wonder that rural energy development projects, ostensibly founded on people's participation, often fail to provide benefits to the target beneficiaries.[1]

Based on field observations and reports, especially those with relevance to hill areas, the author of this paper has tried to analyze factors constraining or contributing to useful participation in rural energy programs, The analysis suggests that there are no short-cut methods of promoting participation, which could involve promotion of autonomous local institutions, sharing of values, and imparting multidisciplinary skills to the villagers. This calls for reorientation of extension methods with greater stress on development of local capabilities, especially among women and the economically weaker sections, and integration of energy programs with those of poverty alleviation.

THE CONCEPT OF PARTICIPATION

The importance and need for people's participation in development programs is well recognized (FAO 1973; United Nations 1974; ESCAP 1977). However, the term "people's participation" is ambiguous and often used loosely to describe any involvement of people in a program. Some researchers have tried to be more specific and have defined the term as "commitment on the part of the individual toward all forms of action by which the individual can take part in the operation without being conscious of any socioeconomic barriers to achieve certain common goals in a group situation" (Santhanam 1982), or "the involvement of a significant number of persons in situations or actions which enhance their well-being, e.g., income, security, or self-esteem" (Cohen and Uphoff 1980). For our purpose, however, it is more instructive to discuss the various dimensions of participation that explain the concept and its implications in the context of energy development programs in rural areas. For this, we need to look at three dimensions of participation: who is participating; what kind of participation is it; and how is participation occurring?

Who is participating?

In a rural society, the principal participants in a program would comprise a minority: the rich section of the population, who often take the lead in any new venture, e.g., Dasgupta (1977). This is also true for energy programs as described earlier.[2] While a case can be made for subsidizing the rural rich when the new technologies have a demonstration value, participation is often sought from the economically weaker sections of the population too. Various social and institutional constraints prevent this section of the population from partaking in the benefits in the desired manner, and the bulk of benefits are captured by the less poor.[3] Participation of the poor often implies a struggle to overcome constraints. For this reason, participation is also described as an evolving process accompanied by corresponding changes in economic and social relations (Bhaduri and Rahman 1983).

What kind of participation ?

This dimension of participation distinguishes between participation at different stages of a program. Every program runs through various stages, from problem identification to implementation and follow-up. People's participation can begin at any stage. It is desirable to have a process of participation and feedback from an early stage, so that no efforts are wasted due to non-acceptance of ideas later. For example, with respect to programs on improved cooking stoves, it is suggested that women using the stoves should be directly involved in design (Shaller 1981). It is also suggested that all innovations in the cooking energy system be undertaken only in continuous interaction with women at the idea/conceptual stage itself (Batliwala 1983). This may not be possible in all situations. However, it can be appreciated that early involvement contributes to greater responsibility felt toward a porgram, bringing out the energies and talents of participants essential for a program's success.

How is participation occurring?

Participation generally implies voluntary involvement, though it may be coerced or disguised. With increasing targets set for diffusion of alternative energy technologies like smokeless stoves or solar cookers, such situations are quite likely unless the demand for these items comes from the villagers themselves. For example, in a survey conducted after a program to introduce the above technologies, nearly everyone considered the technologies to be "useful", but only 13 percent and 1 percent were willing to invest in the smokeless stoves and solar cookers respectively, and none did so. In fact, solar cookers were reportedly being used for storing clothes, and the mirror for shaving (Vidyarthi 1985a). In these programs, the motivation to participate had come from provision of the mentioned items free of cost.

Local participation can, thus, take different forms. While it is important to distinguish genuine and disguised participation, it is also essential to understand factors affecting participation in order to arrive at a participatory development process.

FACTORS AFFECTING PARTICIPATION IN RURAL ENERGY PROGRAMS

Program stages may be broadly classified under four headings: problem description, appraisal of alternatives, project organization, and monitoring and follow-up. Although presented separately, these should not be seen as distinct stages, overlaps are easily possible in actual working conditions.

Problem description

The energy problem itself is described differently by various groups of people with opposing viewpoints, e.g., global vs. local, rich vs. poor, or male vs. female. Lack of understanding of these differences could lead to steps in the wrong direction and consequent lack of participation in a program. Continuing deforestation and awareness of the inadequacy of conventional energy sources like coal, oil, and electricity to meet the energy needs of rural ares has led to increasing concern for the introduction of technologies for utilization of new and renewable sources of energy (Parikh 1976; Reddy 1981). In contrast with these macroconcerns, it has been seen that a villager's energy problems and concerns are often related to conditions of poverty, accessibility of resources, and social organization (Briscoe 1979; Vidyarthi 1984). This often contributes to important differences in how the energy problem is described at the macrolevel vis-a-vis the village level.

Similarly, considerable differences may exist between the energy needs expressed by the poor vis-a-vis the rich segment of village population. The distinction between "needs" and "expressed needs", or demands, is important. Although there may be a "need" for a source of energy by poor villagers, lack of resources in cash or kind may prevent them from turning it into an effective demand. A problem description based only on an understanding of needs is inadequate for generating local interest. Instead, a program centered on demands would lead to far greater participation of people. This might mean a different problem description for the poor vis-a-vis the rich. For example, although cooking fuels constitute one of the major components of energy used in a village, availability of alternative cooking fuels may not be considered a priority among the poor inhabitants, even if there is an apparent fuel scarcity in the village. As observed in a village in Uttar Pradesh, despite increasing use of less preferred fuels like spring plants, agricultural residues, and dungcakes, and significant person-hour involvement in the collection of fuel, even women had investment priorities linked to an improved irrigation system rather than alternative cooking fuel (Vidyarthi 1985b).

Similarly, it was found in the study of a village in Gujarat that "though firewood collection has become more tedious because of denudation of forests and restrictions on entry, the women do not see it as their main problem. Their principal requirements are in relation to their more basic requirements". Accordingly, the authors have concluded that "the firewood problems of the poor women will not vanish unless it is seen as part of the symptoms of poverty"

(Nagbrahman and Sambhrani 1983). Problems and priorities would, of course, vary in different situations. In an action research program in the hill regions of Nepal, it was observed that while in one village, situated at a relatively lower elevation, the community favored setting up a biogas plant for milling of rice, the inhabitants of another village, at a higher elevation, placed priority on fuel-conserving stoves for cooking (Bajracharya 1984).

It is also important to be conscious of possible differences in opinion between men and women. The subject of cooking fuels is directly associated with daily chores in the lives of women, so that the associated problems might not be given the same importance by men. There have been instances when women have protested against decisions taken by their own men[4]. It is, therefore, essential that their opinion is taken into account for ensuring their participation.

Thus the need for arriving at a proper problem description before determining program details becomes clear. An important question relates to the method of doing so in the most optimal manner. Some methods popularly known as Rapid Rural Appraisal (Chambers 1981), Gaun Sallah (Messerchimdt 1982), and Sondeo (Hilde Brand 1979) provide illustrations of alternative approaches. The essential point, however, is to arrive at ways of establishing a dialogue with villagers on subjects of common concern.

Appraisal of alternatives

Once the problems have been identified, alternative approaches must be determined and their socioeconomic feasibility assessed. Methods of desk appraisal including social cost-benefit analysis techniques are now well established (Barnett 1978; Bhatia 1977; Smith and Santerre 1980), but these only provide preliminary criteria for the choice of a system. The final answer has to come from the villagers themselves, as the methods of appraisal followed by them determine their participation in the program.

It must be mentioned that methods of appraisal become distorted when the participants realize that a certain system is being given to them as a grant. This is often true in development programs or when there is a high subsidy content. The appraisal method then is no better than a bargaining stance to get the most out of the sponsors. The participation of the people in such projects could be undesirable from the standpoint of project objectives. Initial enthusiasm is likely to wither away with the departure of the sponsors. Grants may be necessary in certain circumstances for demonstration or infrastructural facilities. However, here the issue is appraisal of projects that are to be carried out under circumstances in which replicability would be sought. Thus grants or subsidies in the project should be counted in the appraisal only as they apply to a general situation.

For determining local criteria for appraising a project, it is essential to ask who is doing the appraisal and under what conditions. Among different criteria, removal of drudgery is seen as important by all, but only the rich can afford to invest. Similarly, while most would appreciate savings in cost, the nature of costs could make a difference. Thus, one could expect genuine interest in projects leading to visible savings contributed by,for example, reduction in kerosene consumption. But indirect savings contributed by improved manure from a digester may not be appreciated. Assessment of opportunity costs would be situation specific, and savings in time associated with an activity like fuelwood collection may not be seen as an important advantage by the poor, especially in terms of cash investments.

Projects with cash benefits would, of course, be accorded highest priority. Such projects would generally be appraised by the poor on the basis of net cash inflow under minimum risk conditions. For example, in an ongoing project on development of an integrated dairy system being coordinated by the author, the project components include: (1) establishment of a community center for processing of milk to ghee (clarified butter); (2) biogas for heating; and (3) fodder plantation for cattle. The participating villagers, mostly economically less advantaged families, have initially chosen to invest in the first component only, using purchased firewood for heating in the initial stage. They feel that investment in biogas and fodder plantation should be undertaken at a later stage after the principal loan for the first component has been repaid. Here too,final approval from the villagers came only after assurance from the promoters that in case of a sustained loss, the promoters would take possession of all machinery and equipment after repayment of the fixed capital component of the loan and the corresponding accrued interest. In this case, it was clear that the participants were not in a position to incur any financial risk, some being already burdened with debts and obligations.

Project organization

Project appraisal at the local level often goes hand-in-hand with exploration of organizational alternatives, especially with respect to decision-making arrangements and the organization of material and financial resources.

Decision-Making Arrangements at Local Level. It is often the case that even if a majority of the participants or beneficiaries of a project are from economically underprivileged families of a village, the decision makers are still the powerful rich or their associates. This leads to a lack of people's trust in the project activities and a disguised participation, if any. This may not be easily apparent to an outside observer unless an effort is made to probe the social relations among the participating villagers. For example, in village woodlot plantation, the normal procedure is to appoint a village committee for local decision making. Choice of local members in the committee, specified in terms of being a woman or belonging to a poor family, is often left to the discretion of the village head. Also, he is generally the sole contact person in the village for the program organizers. The head and his associates, or in effect the head himself, is thus supposed to represent people's interest in the program.

In contrast, it is worth noting the manner of involvement of villagers in microhydro projects of the National Energy Administration in Thailand.[5] Participation of a family in the project is determined by the contribution of a stipulated amount of labor time to be shared equally by all participating families. Every participating family has the right of a single vote for arriving at local decisions. Thus, families of all classes are able to participate on an equal basis with minimal distortion, leading to a keen sense of involvement and interest in the project often lacking in the forestry program mentioned earlier.

Organisation of Resources. The organization of material and financial resources could involve a considerable amount of persuasion and negotiation at the local level, especially in community projects involving the poor. In the absence of any meaningful precedence, the poor generally view all activities with skepticism until the results prove beneficial.

In afforestation projects, for example, fencing of the land is often resisted by a section of villagers who traditionally used it for grazing. Such a situation can only be resolved through agreement on provision of grazing rights on a different piece of land, or special permits to these families for cutting grass from the fenced land.

For labor requirements, though "Sharmdan" (voluntary contribution of labor) could be encouraged, it should not be considered a measure of the extent of participation in community projects. It should, however, be expected for certain household technologies like improved cooking stoves. For example, if the beneficiary is not willing to arrange for mud for the construction requirements, then his/her interest in the program is doubtful.

Organization of financial resources can also be problematic. Even though the participants may wish to take a position of minimum risk, the financial institutions have their own expectations, which must be fulfilled. For example, it is necessary to provide security for a project loan. The manner in which this is shared by participants or a magnanimous supporter can indicate the nature of their participation in the program.

Monitoring and follow-up

Monitoring and follow-up tend to recieve the least attention in most projects. As a result, it is not difficult to come across situations where a newly introduced technology is left unused by the beneficiaries. An often quoted example is that of smokeless stoves, where inadequate follow-up after programs of training and construction has led to decline of users' interest. This can only be avoided by strengthening the follow-up component of the program.

It is clear from the above discussion that local participation in energy programs cannot be taken for granted; it depends on a number of factors associated with proper identification of problems, organization of people, determination of resource options and follow-up. This requires an innovative multidisciplinary approach, together with considerable flexibility and commitment on behalf of the extension agents or institutions. The typical extension approach is, however, quite inflexible and mechanical. As rightly observed, "in accordance with the concept of extension, (extension agents) transform their specialized knowledge and methods into something static and materialized and extend them mechanically to the peasants" (Friere 1973). Such attitudes require radical reorientation or else development programs will continue to suffer from a lack of people's participation. Some approaches to participatory development are discussed in brief in the following section.

APPROACHES TO PARTICIPATORY DEVELOPMENT

It is evident that in the context of participatory development, energy programs cannot be seen in isolation from the overall process of rural development. Specialists tend to follow a fragmented approach to development that limits the perspective of problems, needs, and alternatives. Thus, a typical energy planning exercise involves analysis of energy consumption patterns and resources to give an estimate of patterns of demand and supply respectively.

These are sought to be balanced through available conversion mechanisms in the most optimal manner. Villagers, however, may not look at the issues in such simplistic terms. They have a better understanding of problem interlinkages at the local level, a continued faith in time-tested indigenous methods and technologies, and a keen awareness of sociopolitical implications of development alternatives.

For example, an energy planner may feel surprised at looking the amount of common land lying unused in a village, and may be tempted to suggest planting trees for better utilization. A local villager would know, however, of controversies surrounding misuse of common land, its forceful occupation by some, and the futility of any attempt to plant trees on it in the absence of an organizational system to protect them or share its produce.

For an outsider, a complete understanding of such covert issues could mean considerable involvement of time and resources. For a participatory development process, however, it is essential to arrive at a method by which these issues could be taken into account in program development and implementation. The approach suggested here involves development of local capabilities among the villagers, including development of a suitable organization and skills to tackle various problems, leading to the fulfillment of commonly held goals and values. These are discussed in detail below.

Development of local capabilities

Organization and Leadership. The role of a suitable local organization or leadership in an energy program has to be viewed in terms of the nature of interventions, and the support required at the village level. Interventions are often organized because of the inability of poor households to master adequate resources for a project individually. The coordination of various inputs and distribution of benefits in such a program calls for a suitable organizational system with defined roles and responsiblities of the participants.

Although people's organizations are generally already in existence at the village level in the form of village councils presided over by a village head, the role and usefulness of such an organization is limited by the extent to which it represents the interest of different segments of the village population. This also determines the nature and extent of their participation in any activity organized by the council.

An important question in the context of program implementation then is whether the program should be organized around on existing organizational framework,perhaps through formation of committees under existing leadership, or should alternative organizational structures and leadership for such a purpose be exploited? An answer of this question can only be determined by the villagers themselves, through examination of organizational alternatives that allow a democratic decision-making process.

An associated policy question here is: how long would it take to organize a program in the above manner? This answer would depend on the nature of existing organization in the village. While the existence of a well-represented organization or leadership would imply considerably reduced efforts on the part of the project initiators, its absence could imply sustained efforts at formation of a suitable organizational structure. The process could involve conflicts and contradictions at different stages. These are natural to any process of change, and associated time uncertainities should be borne in mind at the time of project formulation.

Training. A proper training program for users or operators of a technical system is essential for effective operation and maintenance of the system. For fuller development of local capabilities, however, mere acquisition of technical skills is inadequate. Instead, it is essential to impart training which leads to acquisition of a set of skills that prepare the villagers to take up all or most of the project responsibilities. Thus, a community biogas project, for example, would also involve management of various aspects of the project and would necessitate training in management skills such as record keeping and accounting.

In certain cases, it is also essential that knowledge of alternative models or designs relating to a technology be imparted so that people can choose appropriate technologies. Training is thus seen as a process of acquisition of a multidisciplinary set of skills by the villagers to organize and run a project themselves, with outside involvement limited to occasionals guidance.

Linkage to goals and values

An essential feature of any development program is that it deals with human beings who have a set of goals and values guiding their behavior and attitudes toward any person or activity. Notwithstanding the existence of suitable local organizations or skills, the success of a program often depends on factors motivating the people, and extent to which program activities are built upon commonly accepted goals and values. To quote an observation made in the context of successful organization,

"The basic philosophy, spirit and drive of an organization have far more to do with its relative achievements than to technological or economic resources, organizational structure, innovation and timing. All these things weigh heavily in success, but they are transcended by how strongly people in the organization believe in its basic precepts and how faithfully

they carry them out !" (Peters and Waterman 1984).

These factors are often pushed into the background by project organizers. This fails to activate the 'human factor' (Rao 1983) essential for bringing about genuine participation. To quote another statement from the same source,

"*The real difference between success and failure in cooperation can very often be traced to the question of how well the organizaton brings out the great energies and talents of its people. What does it do to help these people find common cause with each other ? And how can it sustain this common cause and sense of direction* ?" (Peters & Waterman 1984).

An emerging question is: could there be a common cause among participants, built upon commonly held goals and values in relation to energy programs ? The answer to this question would depend on a number of factors including the nature of existing social relations in the village and the extent to which these are affected by the program.

Without going into detail, social relations in a village are often linked to class or caste associations that could easily be guided by different, often conflicting, sets of development goals.

The manner in which these relations are affected by energy programs would depend on the kind of intervention visualized in the program. In fact, on this basis, energy programs could be classified as follows:

1. No significant change in social relations is foreseen. (For example, simple household technologies for saving fuel, like improved cooking stoves, may have little impact.)

2. A change in social relations is foreseen, but is not effected. (For example, members of the poor class may forsee reduced dependence on others due to potential availability of an alternative irrigation system powered by a community biogas plant, but the existing leadership in the village, belonging to the other class, may prefer to use the gas for cooking and may be able to manipulate events in that direction. Such a situation is not uncommon in community projects with typical bureaucratic intervention that prefers to work with existing organization and leadership, even though it may not represent the interests of the poor majority.)

3. A change in social relations is forseen and is effected. (There is a conflict of goals and interests between members of different classes. However, in this case, a separate elected body is constituted to run the project. This body helps in giving shape to the project with special attention to the goals of the poor majority.

4. A fourth category could include cases where, irrespective of caste or class associations, villagers may collude in a project to move toward fulfillment of commonly held goals like self-reliance or environmental conservation. This category, though relatively rare, is possible only when development agents are able to effectively share basic values such as those concerning human destiny in general.

Participatory development can, thus, be a lengthy process. Depending on the kind of intervention foreseen, it could involve sharing values, developing local institutions, and imparting a multidisciplinary set of skills to the villagers. This raises an important policy question regarding methods of doing so on a large scale. The development of Van Panchayats (locally elected Forest Councils) in the hill areas is a well known effort in this direction. The experiences associated with such a system in promoting local participation in the management of village forests is briefly examined below.

Van Panchayats

The formation of a Van Panchayat generally follows a signed agreement by- one third of the families in a village with the Forest Department to take over management of a forest on village common land in accordance with the Panchayat rules and regulations. These include election of a local government body of "Panchs", headed by a "Sarpanch" who are supposed to meet regularly to decide on methods of protection, extension, and product distribution. The panchayat receives no financial support from the government. Any income accruing from the sale of products, i.e., fuelwood, timber or grass, on the other hand, has to be deposited in the Van Panchayat fund, which can be used for community welfare expenses such as repair or building of village schools or roads. The products could be distributed among the villagers, if the Panchayat decides this. Any lopping or felling is, however, regulated and can be executed with the permission of the Forest Department only, which has appointed Panchayat inspectors to supervise the operations of the Panchayats, including holding their elections every five years.

Investigations of the system indicate that people's participation in Panchayat activities is constrained for several reasons. Restrictions on the utilisation of Panchayat funds, along with the lengthy procedure for obtaining sanction for these, serve to alienate the villagers from the forests. On account of the forest being looked upon as government property, the Forest Department is expected to assist in its management, especially in the punishment of encroachers. Any lacunae or indifference on behalf of the department serves to propitiate mismanagement and corruption. These are accentuated by irregularity in the holding of Panchayat elections. People's trust and participation in management is thus severely eroded.

An ordinary villager's interest in the Panchayat lies in sharing of the products in the form of fuelwood, timber or grass. The management, however, finds it easy to auction the products and obtain ready cash for meeting various administrative expenses. This often leads to discontent among the villagers, especially the economically disadvantaged groups who are unable to benefit from this practice. It is also significant that women play little or no role in the management of the Panchayat.

A Van Panchayat, or any other local institution, can serve a useful purpose only to the extent it develops controls and procedures in the institutional functioning and governance that ensure democratic decision making and adherence to rules and regulations. This also implies strengthening local capabilities, especially of the poor majority, to enable them to participate in decision making effectively.

POLICY PERSPECTIVES

To enhance local participation in energy programs, energy development must be seen in the context of overall development. This implies that even if planning for energy continues to be based on a sectoral approach, local development efforts should have a holistic approach built on development goals and priorities set by the local population. Furthermore, as noted previously, it is important to know who among the local population is participating. If the target beneficiaries constitute the economically weaker sections of the population, local institutions and leadership must be representative of that section. Development of capabilities of such an institution would consist in imparting a multidisciplinary sets of skills, so that the programs are eventually managed by the participants themselves.

From a policy perspective, this implies a need for intermediary agencies and persons having the necessary orientation, flexibility and capabilities to match current macroconcerns and technological achievements to local development requirements. In some countries, like India, an extension mechanism of this nature was visualized in the setting up of block development centers supported by village level workers. The past several years of experience has, however, shown that this has functioned simply as a delivery system for centrally designed programs and targets (Rao 1983). Apart from the absence of a proper feedback mechanism, the system works through local organizations and leadership (gram panchayat and pradhan) often unrepresentative of the interests of the poor majority. It is not surprising, therefore, that program benefits seldom reach this latter section of the populaton.

Alternative institutions like Van Panchayats in hill areas could play a useful role in promoting local participation in energy programs, provided they are backed by proper regulatory mechanisms that ensure democratic decision making at local levels and adherence to associated rules and regulations. For this, it is essential that extension methods are reoriented to strengthen the abilities of disadvantaged villagers, espcially the poor and women, enabling them to participate in decision making more effectively. This is possible only through well trained and motivated staff working at the village level, supported by a system of information feedback and processing that can lead to rapid action, if necessary, inclusion of women extension workers would also go a long way in promoting women's participation in these programs.

Alternatives also exist in working through informal groups and voluntary non-governmental organizations active in similar or associated fields. Voluntary non-governmental organizations have displayed the ability to work as efficient intermediaries between the government and people, with personnel having multidisciplinary skills and values congenial to participatory development. Such organizations can act as effective supplements to the existing extension channels.

CONCLUSION

Participation is not something uncertain or exogenous to a development program. It can be cultivated by adopting an approach that helps to fulfill the goals of the community in question. Energy programs can have varying degrees of contribution towards the fulfillment of such goals. They attract greater participation if integrated with programs for mitigation of poverty and unemployment. Local participation is also facilitated if work is carried out through local institutions and leadership truly representing the interests of villagers. Widespread adoption of such an approach calls for reorientation of extention practices and involvement of voluntary organizations having the necessary capabilities and commitment.

ENDNOTES

1. For example, social forestry programs have been seen to benefit industry with negative effects on the poor (Shiva et al 1982). Biogas program also have essentially benefitted the rural rich (Moulik et al 1978).

2. Such tendencies have been variously described as the 'talents effect' (Pearse 1980) or the 'refraction effect' (Morehouse 1981).

3. As in the case of the women of Dongri Paintoli fighting for forest conservation (Jain 1984).

4. Field notes of the writer.

5. Based on ongoing project on participatory evaluation of fuelwood programs being coordinated by the author.

6. For example, Yuvak Mangal Dals or Mahila Mandals (Youth or Women's Councils).

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THE ROLE OF WOMEN IN ENERGY-RELATED ACTIVITIES IN THE MOUNTAINS

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INTRODUCTION

A major challenge before the developing countries today lies in achieving the desired degree of mechanization and productivity in all sectors, with minimal energy expenditure. Traditionally, men have played a dominant role in production economics and, hence, in energy-related activities. Women, unfortunately left out of the main stream of development, are the pillars on which the future generation rests, and the roots which can stabilize the rural economy. Clear-cut correlations have been established between the education and economic status of women, and the health status of the population and fertility control. Their contribution to production is significant, albeit often hidden as non-remunerative "shadow work". Practically all the domestic work and most non-mechanized drudgery work is done by women, and whatever earnings they bring go directly for family sustenance.

Thus, seen in terms of energy, the role of women is as important, if not more important, than that of men in any habitat, and particularly mountain habitats. While the path of progress for women in general has been hindered due to sociocultural, traditional, and techno-economic constraints, problems due to harsh climatic conditions and terrain in hill areas add to their under-development. Due to inadequate employment opportunities, men often migrate to the plains, leaving the women responsible for the physical and economic well-being of the family. The general difficulties in water lifting, fuel collection, cooking, child bearing, house building and other operations faced by women in any underdeveloped region is all the more aggravated in the case of women residing in the mountains. Hence, women's upliftment is an important factor in the context of any rural development planning.

Recognizing this, the Indian government has made several policy decisions. Priority is being given to women's development through the Ministry of Human Resources Development. Programs on "Development of Women and Children in Rural Areas" (DWCRA), made as flexible as possible to suit local needs, are under implementation. The Department of Science and Technology has a special cell on "Science and Technology for Women" which is identifying and promoting technologies for women under three categories (Devendra Kumar 1983):

1. Technologies for Drudgery Reduction
2. Technologies for Health and Sanitation

3. Technologies for Employment

The Council for Advancement of Rural Technology, Department of Non-Conventional Energy Sources, and other institutions are also supporting the generation and transfer of technologies for women. Many voluntary agencies are giving special attention to women's problems.

While economic benefit through employment is the major concern, this would become possible only if women were at least partially relieved from their household chores, to which they are bound in eking out a marginal existence in a barely bearable environment. Hence, information is needed on time-budgets so the major activities sapping their energy could be identified and alternatives suggested. Only if the opportunity costs entailed do not promote involvement in other remunerative tasks, can one plan strategies for their employment and income generation. Further, this has to be matched with the local situation in terms of resources, physical environment, skill availability, practices in participating in the market economy, and in general, the status of women in the sociocultural milieu.

This paper proposes to analyze these aspects in the context of the Indian Himalaya with the help of data from studies by some authors and various other reports.

TIME AND ENERGY BUDGETING

Surveys have indicated that rural women generally spend up to 16 hours or even more on domestic as well as non-domestic activities, and hardly get enough rest even during pregnancy. Their activities can be divided into domestic and production-oriented.

Domestic Activities

Cooking fuel and fuel collection. Cooking by convention falls into the woman's domain, irrespective of economic or educational status. The majority of rural women still cook on traditional *chulhas* (stoves) which are both inefficient and smoky. High fuel consumption adds to the burden of fuel collection and also indirectly affects the environment in terms of deforestation, erosion, flooding, etc. *Chulha* smoke containing many irritants and carcinogenic compounds has been shown to be as detrimental to health as smoking several packets of cigarettes a day. The level of pollution caused by a smoky *chulha* in a kitchen is reported to be 10 times or more than that in many thickly populated urban centers of the world. Cleaning is again a woman's problem. Invariably, there is a water shortage making cleaning all the more difficult. A smoky kitchen inhibits the rest of the family from sitting around with the women. Obviously, these difficulties outweigh some beneficial effects due to smoke, such as insect control, and alternatives have to be found, such as occasional fumigation with smoke rather than continued use of inefficient *chulhas.*

The staple foods in rural areas are primarily wheat and rice. Occasionally other cereals like *jowar*, *bajra*, and maize are used. Cooking rice is relatively easy compared to other cereals such as *jowar*. It has been pointed out that efficiency of the cooking device may indirectly lead women to choose cereals which are easily cooked but not necesarily nutritious (Agarwal 1985). To make *chapatis* for a large number of family members causes women to stay near the stove for longer times, as each *chapati* has to be cooked individually, unlike rice.

In the plains, with more intensive agriculture, agro-wastes can be used as fuel and fodder. Buffalo and cattle are kept both for agricultural and domestic use and sufficient fodder is available for them. Thus, animal dung becomes an alternative fuel. Unfortunately, hill terrains are not suitable for agriculture, nor is it easy to get fodder in spite of nearby forests. Often, smaller animals are preferred and dung availability is limited. Women have to use firewood, twigs, and leaves as fuel. Burning of dung, leaves, etc., interrupts the natural nutrient recycling system, affecting the soil fertility in the long run. Also, cowdung has much lower calorific value than wood and is more smoky. Only a few rural and urban women in the higher economic strata can get kerosene or other commercial fuels such as LPG and electricity. Many remote areas have no access to commercial fuels even if the people are able and willing to pay, since the distribution infrastructure is lacking. Hence, rural women continue to use wood, agro-wastes, cowdung, and other kinds of biomass. While the developed world is worried about the fossil fuel crisis, for the developing countries it is a question of finding low-cost or no-cost traditional fuels for cooking. It is feared that even if gains are made available by intensive agriculture, the fuel for cooking may be harder to find. Volumes have now been written on how this "secondary fuel crisis" is affecting the environment and vice-versa.

Unfortunately, in the subsistence economy closely associated with ecology, it is women who are expected to meet fuel needs. While at one time fuelwood was available at the doorstep, now a woman has to walk several hours to collect even inefficient fuels like weeds and leaves. Use of these demands continuous attention during cooking. Particularly in hill areas, deforestation is increasing due to commercial contracting of forests for firewood and for providing raw materials to various industries. Also, in certain hill areas, land availability is reduced due to rights being given for mining and other activities, without considering the effects on ecology and the people. This has increased the number of hours spent by women on fuel collection. In fact, the task has become impossible for the physically weak.

Water fetching and cleaning. Gone are the days when water was easily available in the hills. As a part of the domestic work, women and children are expected to bring water not only for cooking, but also for washing the animals, clothes, and cleaning utensils. The dwindling of water resources has resulted in long hours of walking. Availability varies with rainfall and season. Summer and drought add to the drudgery. Even where pumps or other water-lifting devices have been installed, often these do not have the desired impact due to lack of maintenance. Studies on pully systems, hydrams, and other water-lifting devices suitable for a given area are scanty at the field level, as developments remain confined to the laboratories.

The quality of water also affects the health of the population. The worst hit are the women and children, whose energies are sapped by waterborne diseases such as dysentery.

Housing and Sanitation. Due to economic and traditional sociocultural factors, most villagers live in *kachha* houses made of locally available materials. While men spend their time working outside or migrating to urban centers, women are confined more to their village and homes. Thus, any problem associated with inadequate housing, such as ventilation or leakage, affects the women most. Further, cleaning the house as well as repairing takes a lot of time and energy.

Inadequate sanitation is a direct cause of several diseases. Non-availability of toilet facilities compels the women to seek covered areas early in the morning, or late in the evening. With the receding forest cover, they have to walk longer distances and bear greater physical and mental tension. This practice also leads to poor personal hygiene, besides resulting in the spread of diseases, affecting the health of the population as a whole.

Child care. As poor men live by literally working with their hands, children are not considered an additional burden, but an economic advantage. Absence of better opportunities for using women's time on more remunerative tasks, and their low status in the family, with hardly any decision-making powers, have condemned them to repeated child bearing. The average family size is still six or more. Women continue to perform all domestic tasks even during pregnancy. Added ill-effects of poor nutrition leave the women in a state of low-energy equilibrium, with their bodies and spirits dampened by disease and conditions including anemia and protein deficiency. The migration of men to the cities adds an additional dimension to the drudgery. Women simultaneously face biological and psychological pressures in being away from their husbands for long periods, while carrying the physical load of not only keeping body and soul together, but also those of the children.

Productive Activities

Agriculture and animal husbandry. In comparison to the plains, agriculture is more difficult in hill areas. However, the climate supports horticulture. There is no tradition of taking special care of forests and planting trees, since in the past dense forest cover was available; in fact, it was necessary to reclaim land for agriculture by shifting cultivation. With the changing situation, forestry could be an area in which women can play an active role, if given the necessary organizational and financial support.

Women have always participated in agriculture and horticulture, and with the migration of men, their involvement has increased. Modernization and mechanization may raise productivity, but often also add to the drudgery because the division of labor generally leaves the more difficult and tedious tasks to the women. As for animal husbandry, in view of the fodder situation and nature of hill terrain, smaller animals like pigs and goats become more important, especially for meat production.

Other modes of employment. As discussed above, women generally spend most of their time on non-remunerative tasks, and even their participation in production-oriented activities does not bring direct monetary gain. They are also not formally trained for any kind of employment due to their low status and cultural bias against their employment. In fact, even the illiteracy level in most states is very low (Appendix 1), not to mention higher education and vocational training.

Hence, any education or training has to be taken up through non-formal modes. Since women's domestic chores bind them to their homes, normally home-based employment such as cottage industries are suitable. The custom of using local resources to make a variety of handicrafts and utility articles, such as brooms and baskets for nearby markets, is in vogue. However, lack of raw materials is now eroding this. Other skills, including weaving and embroidery, are also vanishing due to lack of proper market support. In fact, the environmental crisis and urbanization have created occupations not in existence traditionally, such as head-loading, in which women collect and sell firewood.

However, opportunities for wage earning become available when the government takes up programs such as road building or when entrepreneurs introduce new activities. Unfortunately, often the women are not paid full wages or given suitable facilities despite legislation to protect their interests. Although government rules prescribe minimum wages, employers generally do not recognize these wage structures as compatible with their profit targets.

In some castes it is considered demeaning for the family to let the women earn; women themselves tend to share this view. Thus, releasing women from domestic drudgery cannot be considered important in a male-dominated society unless her earnings outside are sufficiently lucrative. Much effort is needed to improve the situation, creating self-confidence in women.

CASE STUDIES AND REGIONAL VARIATIONS

The time schedule and energy spent on the above activities not only vary by region, but by village and household, depending on physical, environmental, socioeconomic, and cultural factors. Hence, the case studies have been grouped on a regional basis and each type of activity is discussed in detail.

Himachal Pradesh

Cooking fuel and fuel collection. A sample survey (Khosla 1985) in Mandi and Solan Districts of Himachal Pradesh showed that in these areas firewood is the principal fuel for both cooking and space heating, followed by animal dung and agricultural residues. All households collect firewood; no households in Solan use kerosene, while a few do in Mandi. The villagers unanimously felt that the shortage in firewood supply was increasing due to deforestation, but continued to consume firewood at high levels instead of trying to reduce their consumption. As shown in Table 1, there was a significant difference between the two districts.

Table 1: Fuelwood Collection and Consumption

Household Consumption			Time Spent on Collection	
Consumption (kg/Month)	% Household		Manhours per day	% Household
	Mandi	Solan		
Below 400	41	100	1 - 2	26
400 - 800	36	-	3 - 4	37
Over 800	22	-	5 - 6	37

Mandi villagers, having greater access to forest areas, use wood more liberally both for cooking and space heating, leading to an average consumption of 500 kg/month compared to 220 kg/month in Solan. The high firewood consumption is reflected in the total time spent in collecting firewood (an average of 3.7 hours per day per household). In Mandi, three meals a day are taken, while in Solan, meals only include lunch and dinner. Wherever breakfast forms a part of the food habit, many women have to start cooking before seven in the morning, while in the absence of breakfast, it is possible to start cooking lunch about ten o'clock.

Obviously, the duration of cooking depends on the number of family members. Average cooking durations of 1.9 hours for breakfast, 1.6 hours for lunch, and 2.2 hours for dinner, amounting to a total time of 5.7 hours, are reported in Mandi. In Solan, the average time spent was much less: 1.7 hours for lunch and 1.7 hours for dinner, with a total of 3.4 hours for all meals. Possibly due to less cooking time, firewood consumption in the Solan area is lower. However, more wood is consumed for space heating in Mandi.

Types of *chulhas* used in this area were also surveyed. Over 90 percent of the households in Mandi and all households in Solan possess only one *chulha*, while 8 percent in Mandi use two *chulhas*, While the first *chulha* is generally made of clay/stone, the second is often made of metal. It may be noted that especially in the Solan area, three-pot *chulhas* are common. The stone and clay *chulhas* have a reasonably long life.

A survey (Roy 1980) on the status of women was taken in some villages of Kangra District. As in other villages, the women collected wood. Seventy percent of the women travel more than 6 km/day, often accompanied by a male family member. A large majority have to go for fuelwood collection to the forest every day and spend four to eight hours/day. During monsoon, wood collection and burning are tedious, but over 80 percent of respondents collected at least 19 kg of fuelwood per week, and over half of these collected more than 40 kg.

The fuelwood collected bears a positive correlation with time as shown by a regression equation:

$$Y = 21.75 + 2.6 X$$

where X = Time spent collecting fuelwood in hours

Y = Quantity of fuel collected

The regression coefficient was found statistically significant at one percent level of probability.

The type of fuel used is basically firewood and occasionally some households also use coke. Use of kerosene was negligible. The species of trees that are used as fuelwood are: *Bann* (*Quercus incana*); *Brah* (*Rhododendron arboreum*); *Buel* (*Grewia Optiva syn-oppositifolia*); *Ohi*(*Olbizzia stipulata*); *Fulnu* (*Lantana camara*); and *Funna* (*Ehretia acuminata*).

Women's problems in fuel collection were as follows:

	%Households
1. Forest is too far from where wood is collected	40.7
2. Large family size leads to greater fuel consumption	66.9
3. Difficulty during monsoon	100.0
4. Fuel collection is tiring	85.0
5. Fuel collection is time-consuming	92.6
6. Tools are not available for felling	33.3
7. Punishment by forest guard is too severe	40.7
8. No fuelwood depot in the village	33.3
9. Expensive to purchase trees for fuel, so it is collected	70.3

Survey (Varma 1985) data on five villages in Solan and four villages in Simla District of Himachal Pradesh are shown in Tables 2 and 3.

Table 2: Type of Fuel Used in Solan and Simla Districts

Type of	% Households	
Fuel used	Solan	Simla
Wood	100	100
Dungcake	22	-
Coal	5	-
Kerosene	7	20
Agricultural Waste	-	-

Table 3: Fuelwood Collection and Consumption

Household Consumption			Time Spent on Fuel Collection	
Consumption (kg/month)	% House		Manhour (per day)	% Household
	Solan	Simla		
Below 400	42	61	1-2	41
400 - 800	51	21	3-4	59
Over 800	7	18	5-6	-

The major source of fuel in these villages is wood. Agricultural residues are generally not used. The average time spent on fuel collection is three to four hours with an average fuel consumption of about 450 kg/household/month. No shops sell wood or coal; fuel is only collected from the forest. The practice of carbonizing wood into soft coke isprevalent in this area for the production of coal for home consumption.

The State Social Work Research Centre (SSWRC) in Chopal, and Social Upliftment Through Rural Action (SUTRA) in Jagjit Nagar, have taken up the propagation of improved stoves in the villages. Mostly people use two- or three-pot stoves for cooking. Only a few families have coal *angithi* (heater) for space heating. The average time spent by women in cooking is 3.5 to 4 hours.

The women's perception of difficulties and drudgery involved in cooking-related activities is seen from their responses as shown in Table 4.

Water fetching. Ponds, streams, and ground water were the main sources (Khosla 1985) of drinking water in most villages. A Public Water System was, however, available for Banan and Kumkar villages in Mandi District and a few others in Solan and Simla areas. The average distance of water sources from various houses ranged betwwen 1 and 4 km. Over half the houses in Mandi, and three-quarters in Solan, spend more than three hours/day collecting drinking water, involving several trips (Table 5).

Table 4: Women's Perception of Drudgery in Cooking

(a) Tiring Factor			(b) Wish to reduce cooking time		
Operation	% Household			% Household	
	Mandi	Solan		Mandi	Solan
Smoke	74	100	Yes	94	98
Blowing	20	-	No	6	2
Others	6		-		

Table 5: Water Fetching

Time Taken for Collection			Number of Trips		
	% Household			% Household	
	Mandi	Solan	Trips	Mandi	Solan
Zero	8	-		7	
Less than 30 min	2	2	1 - 3	6	9
30 min - 1 hr	7	1	4 - 7	18	41
1 hr - 2 hr	14	12	8 - 12	36	30
2 hr - 3 hr	11	14	Over 12	32	21
More than 3 hr	57	70			

The perception with regard to the difficulty in water fetching is seen from Table 6. Surprisingly, quite a few women do not consider this a drudgery and in fact only about 15 percent of the respondents were willing to spend over Rs. 5 per month for water.

Table 6: Perceived Extent of Effort vis-a-vis Time Taken to Collect Water

Time Taken	% Respondents		
	Not Much	Much	Too Much
Zero	100	-	-
Less than 30 min		86	14
30 min - 1 hr	69	13	19
1 hr - 2 hr	46	22	30
2 hr - 3 hr	18	26	56
3 hr	2	14	84

A similar pattern was seen in the villages near Jagjit Nagar and Chopal.

Housing and sanitation. In the villages of Solan and Simla Districts, the houses are made of wood and do not have sanitation facilities. The women generally do their washing, cleaning, and bathing outdoors. Also, they have to walk to the nearby forests for defecation. Forty-seven percent of respondents in Mandi and 97 percent in Solan District (Khosla 1985) desired covered latrines and quite a few indicated their willingness to pay for public latrines for day-to-day usage/or for building private latrines.

Productive activities. Eighty percent of the women in Mandiand 77 percent of the women in Solan (Khosla 1985) render help to men in their activities. In fact, as shown in Table 7, hardly two hours of leisure time were available to the women. In this area, about 75 percent of the women showed willingness to learn new skills and generate income. Interest with regard to various activities was in the following order:

Table 7. Available Free Hours for Women

No. of Hours	Figures in Households Percent	
	Mandi	Solan
Nil	1	7
1	14	19
2	60	48
3	19	14
4	3	4
5 or more	2	4
No comment	2	3
Average (Hrs)	2.2	2.2

Stitching > Horticulture > Knitting > Basket weaving

Activities undertaken by women in Solan and Simla area are: wool spinning, basket making, vegetable growing, and kitchen gardening. SUTRA is helping by giving vegetable seeds. The women are also involved in agriculture and animal husbandry (mainly cattle and buffalo), and labor for construction work.

Uttar Pradesh

Cooking and fuel. An energy survey (Satsangi 1981) in hill areas of U.P. in Nainital District showed that consumption of fuelwood is 2.61 m^3/capita. This is reported to be much higher than the consumption in the U.P. plains and is attributed to the need for space heating and easy access to forest wood. Cooking is done on the *chulha*, using noncommercial fuels. Though in these hill areas livestock are kept, the dung is used mainly for agriculture, rather than as fuel in the households, since the local people prefer wood to smoky dung. Similarly, vegetable waste is also used for agriculture and as cattle fodder. Seventy-one per cent of the fuelwood is used in cooking, 16 percent for space heating, and 12 percent for water heating. Almost all the households collect fuelwood and the time spent is increasing, as the villagers have to walk farther to reach the rapidly depleting forests. In some parts of the U.P. hills, women trek over 10 km a day and even camp in forests, returning the next day. School children also collect wood. The average time is 1.64 hours per household per day as compared to the plains of Nainital where it is 2.37 hours/household/day.

The consumption of firewood in Almora and Pauri Districts (Khosla 1985) is shown in Table 8.

Table 8: Fuelwood Collection and Consumption

Household Consumption			Time Spent on Fuel Collection in U.P.	
Consumption (kg/month)	% Household Almora	% Household Pauri	Man-hours (Per day)	% Household
Below 400	78	72	1 - 2	19
400 - 800	21	23	3 - 4	56
Over 800	-	5	5 - 6	-

Very few people use kerosene in Almora, while more than half the villages in Pauri District were using kerosene. While monsoon is the season of low availability of firewood, variations are not otherwise sharp, and the average collection time per household was 3.9 manhours per day.

In Almora 98 percent of the households use two *chulhas* while in Pauri, 60 percent possessed only one *chulha* and 38 percent use two *chulhas*. A two-pot chulha was used in 60 percent of the cases in Pauri and 93 percent of the households surveyed in Almora. The average time spent on all meals in Almora was 4.1 hours, while in Pauri, it was 4.8 hours.

In the Himalayan village of Dwing in Chamoli District of U.P., on average, one or more members of each household (generally women) walk 5 km uphill and spend 6 to 10 hours per day collecting fuel (Agarwal 1985). The average time spent per household was 7.2 hours.

Pakhi is a prosperous village with a major road passing through it, but even here 86 percent of the household women collect fuelwood. The average distance travelled in collecting wood is 3.1 km, and half the household make daily trips.

A survey of Mahua Dabra of Nainital District (Agarwal 1985) showed fuel consumption ranged from 250 to 300 kg per month, depending on the number of family members. In addition, the households use 5 to 6 kg of dungcake per day. Firewood is generally collected from nearby forests.

Water fetching. The following figures have been reported (Khosla 1985) on time spent in water collection in Almora and Pauri (Table 9). As in H.P., more than half of those spending less than three hours on water collection did not perceive the effort as drudgery. However, 83 percent of those who had to spend more than three hours on water collection felt that the effort was too much for them.

Table 9. Water Fetching

Time Taken for Collection			Number of Trips		
Time	% Households		Trips	% Households	
	Almora	Pauri		Almora	Pauri
Zero		None			
Less than 30 min	7	2	1 - 3	4	10
30 min - 1 hr	9	20	4 - 7	58	60
1 hr - 2 hr	16	40	8 - 12	35	23
2 hr - 3 hr	11	16			
Over 3 hr	57	22	Over 12	2	7

Housing and Sanitation. As in other villages, sanitation facilities were lacking but women's perceptions differed. In Almora, 85 per cent of the households desired latrines, whereas only 8 percent considered this necessary in Pauri. In fact, in these areas, very few showed willingness to pay for public latrines.

The housing pattern in various villages in these districts were similar, and generally locally available materials were used. The villagers perceived the roof structure and walls of the houses as inadequate.

Productive activities. The 1981 census shows that in U.P., female work participation rates in the five hill districts of Chamori, Tehri, Uttar Kashi, Pathoragarh, and Garhwal range from 32 to 49 percent as against the state average of 6 percent. Between 96 and 98 percent of the female workers are cultivators who do everything on the farm except ploughing. A large proportion of women did not exhibit much enthusiasm to acquire additional skills as they had less than two hours to spare. Twenty-nine percent of the women in Almora and 97 percent in

Pauri help men with their activities. Women, however, showed interest in learning knitting and stitching.

Jammu and Kashmir

A socioeconomic survey (Awasthy 1979) was conducted in the village of Jagti approximately 17 km away from Jammu and Jammu-Udhampur National Highway. The village is populated by Gujjars, Brahmins, Rajputs, Lohars, and other scheduled castes. The survey has brought out the differences in the lifestyles of women from various castes.

In the village, people mainly eat *fulka* (*chapati*, or flat bread) with milk products or vegetable/dal. Practically everybody uses firewood and a *chulha* on the ground. Only two to three families out of 45 use kerosene. No one buys firewood; it is collected from the jungle or their land. However, Rajput and Brahmin women operate in their own fields. Since wood cutting requires physical strength, in 16 out of 45 cases the male does the cutting. In the caste groups such as Rajputs and Brahmins, in more than 40 percent of the households, menfolk undertook this work because traditionally these women do not go out of their homes. The other household activities such as cooking and cleaning are done by the women. Women's contribution in dairying and agriculture is significant, except in the case of Rajput women who consider this below their dignity. Most families grow enough grain for six to eight months but since the land is dependent on rainfall and very few people can afford to dig tubewells, the land is also left fallow or ploughed once in two years.

Northeastern Hills

The northeastern states are hilly and covered with thick forests receiving high rainfall. The population density is low and more than 90 percent of the people live in villages depending on agriculture and horticulture. The people are predominantly tribal. Among most of the tribal communities the status of women is not low. In fact, in certain matrilineal tribes, women enjoy a better position than men.

A study of the villages of Shella and Tyrana in Meghalaya (Das Gupta 1984) shows that rice is the staple food. Meat forms an important item on festive occasions. As for fire and lighting, safety matches are used, while about 50 years ago the people used flint for making fire. In the age of flint, fire used to be preserved and a dry branch of orange tree was kept smouldering on the hearth all day and night.

In Shella village, for cooking, the hearth is made in a rectangular or square wooden or bamboo frame which is movable. The pit within the frame is filled with earth and three stones are embedded in it. The pot is placed on this. In Tyrana village in some houses, the hearth is contructed in a different manner. The houses are constructed using locally available materials such as bamboo and wooden poles. The roof is generally sloped and thatched with a type of palm leaves knows as *slatynrin*. In his area, heavier work like construction and repairing of houses is done by men and not by women. The families in this area are small in size, varying from two to five.

A survey (Julia 1984) of some of the villagers in the Garo Hills (such as Dadengiri or Tura) located in the interior of the state, showed that generally open fire *chulhas* are used for cooking. In this hill area, there are a lot of insects and smoke from the *chulha* helps in mosquito control and curing bamboo thatch. Further, the practice of smoking meat exists. Thus, the women do not perceive anything bad about smoke. They generally use separate fires for each cooking hole. Also, fuelwood is easily available and fuel consumption is about 4 to 5 kg/day/household. Wood and twigs are collected from the jungle, and fuel collection takes less than an hour each day. Rice is the staple food and two meals are taken. The morning meal around 10 A.M. takes about two hours of the women's time and evening meal takes two to three hours of preparation. Rice and dried fish or yam are eaten around 6 and 7 P.M. Water fetching is, however, seen as a difficult task in these villages as women have to walk 2 to 3 km, taking four to five hours for fetching water. Normally one trip is made a day. Houses in the area are made of bamboo, and durability is about three to four years.

From a survey (Srinivasan 1985) of households peripheral to Shillong, Meghalaya, it was seen that women here spend about two hours a day on cooking. Mainly two meals of rice were eaten. The time spent on firewood collection was generally less than one hour and there were two *chulhas* in most homes. Coal was used in space heating. Water fetching took one to two hours. Women went out to work in the field or did other odd vending jobs for five hours and some kept milch animals. There was no sanitation facility.

As for productive activities, in the northeastern states, the women participate mainly in agriculture and animal husbandry. Shifting cultivation is still being practiced in many places and the main crop raised is rice. In addition, various fruits and vegetables are grown. Also, small animals are kept (Singh 1985). The 1981 census shows that the proportion of women in the work force is high in most mountain areas, varying from 41 percent in Nagaland to 32 percent in Mizoram.

Geographically, Manipur can be divided (Das 1984) into the valley at the centre with the hills surrounding it. The forest trees perhaps covered the valley earlier but now they have disappeared. The rich alluvial soil is a boon to the cultivator. Terraced fields are irrigated throughout the year. However, wet cultivation practiced on a small scale seems to have an adverse effect on women's employment. Small groups, both male and female, from the same village visit the market. Now women have started selling products like dried fish, matchboxes, and sweets, but over 86 percent of the Manipur hill tribes are agriculturists (Singh 1984). They grow paddy and to some extent maize, fruits, and vegetables. The custom of keeping poultry is predominant. Houses are small, with walls of bamboo on raised floors of bamboo and wood.

STRATEGIES FOR DEVELOPMENT

The above survey has shown that the overall pattern of activities of women in the mountains is similar to those in the plains. Differences arise due to the uneven terrain and colder climates. For example, in the mountain areas, ploughing is more difficult. Where terracing has to be done, women undergo the additional drudgery of breaking and spreading the mud mounds. They also have to climb up and down in going to their fields and also for fetching fodder, fuel, and water. Where forests are still available, the fuel problem is less acute compared to the plains, but the time required to reach forests for wood in the mountain areas has been increasing. Compared to the plains, transportation in the mountains is difficult and kerosene and other alternate fuels are not available. Even dung availability is less. Lack of infrastructure also results in non-accessibility of markets.

Within the hill areas studied, broad-based differentiations between regions are difficult to make. The economic status, caste, local geographic factors, and infrastructure availability have a great role to play. Certain traditional and cultural aspects and practices are seen to be region-specific, while others are universal. For example, cooking and cleaning as well as child care are seen as the activity of women in all areas. Fuel collection and water fetching are also done mostly by women. But in certain castes, women do not go outside their homes and any task which is not home-based has to be taken up by men. The eating habits do have some regional specificity. In the northern regions (Himachal Pradesh and Uttar Pradesh), *chapatis* form the predominant diet. This requires more cooking time. In the northeastern regions with rice eating habits, women spend less time cooking. Although deforestation is common to all the regions, in the northeastern part, wood and other biomass seem to be more easily available. Thus, the women here spend less time on fuel collection as compared to their counterparts in the northern sector. Also, in the tribal culture of the northeastern region where matrilineal social structure still prevails, women enjoy better status socially and economically.

In general, a dismal picture of the present situation of women in the mountains emerges. The basic domestic tasks of providing food, water, and fuel for the households, fodder for the animals, and tending children were not too difficult in a traditional society under better ecological conditions where the women were equal partners in resource sharing. In fact, in many primitive cultures the position of women is even better than that of men. Unfortunately, industrialization, urbanization, and advancement of the cash economy have eroded the basic biomass resources through deforestation and devegetation, but have not brought any benefit to the poor and marginal cultures like tribals and nomads. They are compelled to continue within the non-monetized biomass-based subsistence economy in an ever-eroding environment. They are divorced from the benefits of industrialization but are made to bear the brunt of all its negative impacts. In particular, the poor rural women who are caught between poverty and environmental destruction suffer most. With the migration of men, their days are marked by a double work burden, at home and outside, in an unsympathetic physical and social environment. With the added problems of inferior status, lack of control over cash and productive resources, lack of health care, sanitation and other facilities, which are biologically essential to this child-bearing sex, they are now being pushed beyond the limits of physical endurance.

Alleviating Drudgery and Creating Leisure

The time that women spend on mundane activities, assigned in terms of their sex role, must be reduced. For example, giving access to fuels, providing them with improved *chulhas* for cooking, and giving drinking water facilities could easily create a few hours of leisure. Wherever possible, low-cost technologies should be designed and introduced for reducing their drudgery. Some examples are listed in Appendix 2.

Improving Health and Physical Environment

This can be best done through informal education, making the women literate and aware of the basic concepts of nutrition, family planning, child care, sanitation, making them conscious of their roles in development, creating self-confidence and organizing them to receive the benefits of various schemes for the upliftment of women. This calls for special efforts of dedicated voluntary agencies, working hand-in-hand with the government and Science and Technology field agencies.

Economic and Social Status

In a monetary economy, improvement of economic status and social status are interlinked. Presently, the opportunity costs prescribe involvement of women in remunerative tasks. They are not sufficiently equipped in terms of skills and training. to participate in a mechanized production system and the market economy as a whole. Difficulties are added due to cultural bias with regard to their sex. Technologies suitable for home-based employment have to be propagated with the necessary managerial and market support (Appendix 2).

CONCLUSIONS

Hindu mythology visualizes the Goddess of Power and Energy as "Shakti"--woman, daughter of the Mighty Himalaya. Nothing could be more appropriate, considering that today the rural woman in the mountains is central to energy, ecology, and environment as a whole. It is through her that the human habitat interrelates with the surrounding forests, mountains, streams, waterways, and animals. It is from her strength that future generations evolve and prosper. No efforts should be spared to free her from her shackles and lift her to the heights she deserves.

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APPENDIX 1

Literacy of Women in Hill Areas (Mitra 1979)

	Percentage Literacy					
	Excluding SC/ST		SC		ST	
	1961	1971	1961	1971	1961	1971
1. Jammu & Kashmir	1.62	5.14	0.88	3.49	-	-
2. Himachal Pradesh	6.36	21.76	-	8.99	1.71	5.45
3. Uttar Pradesh	4.60	8.56	0.68	1.74	-	4.33
4. West Bengal	12.66	18.78	3.83	8.23	1.60	2.77
5. Meghalaya	-	13.85	-	12.24	-	19.65
6. Nagaland	26.35	24.14	40.00	-	9.68	4.02
7. Tripura	11.23	26.14	4.23	8.95	1.55	4.02
8. Manipur	13.00	16.03	12.28	15.71	17.48	17.59
9. Arunachal	-	12.70	-	17.59	-	1.56
10. Sikkim	13.37	-	-	6.45	-	-

SC - Scheduled Caste
ST - Scheduled Tribe

APPENDIX 2

TECHNOLOGIES FOR WOMEN

(Devendra Kumar 1985)

Drawing and Fetching Water

1. Ball-Bearing Pulley
2. Bamboo-Cement Water Tank
3. Cement Water Jar
4. Roof-water Harvesting
5. Knotted Rope Pump
6. Bamboo Water Pump
7. Bamboo Pipeline
8. Waterproofing of Small Irrigation Channels
9. Drip Irrigation

Cooking

10. Improved *Chulhas*
11. Solar Cooker
12. Biogas

Repair and Maintenance of the House

13. Non-erodable Mud Plaster
14. Fire-Resistent Thatch
15. Preservation of Bamboo
16. Rammed Earth Wall

Working on Farm and Farm Products

17. Improved Sickle
18. Wheelbarrow
19. Ball-Bearing *Chakki*
20. Groundnut Sheller
21. Paddy Thresher
22. Pulse Dehusker
23. Maize Sheller
24. *Sheetal* Pot
25. Food Processing
26. Food Preservation
27. Mud-Brick Grain Silo
28. Corn-Drying Hut
29. Improved Traditional Silo
30. *Ferrumbu*

Safe Drinking Water

31. Charcoal Water Filter
32. Traditional Water Purifying Seeds
33. Solar Water Still
34. Chlorination Pot for Walls

Sanitary Facilities

35. Trench Lavatory
36. *Sopa* Toilet
37. Toilet for Two
38. Conversion of Bucket-Privy
39. Soak-pit

Nutrition and Health

40. Breast Feeding
41. Eye Care
42. Weaning Foods
43. Dental Care
44. Birth Control
45. Oral Rehydration
46. Diahorrea and Dysentery
47. Health Salts
48. Delousing

Agro-Based Industries

49. NADEP Compost
50. Bio-Dynamic Gardening

Food-Processing Industries

51. Mud Solar Dryer
52. Solar Paddy Dryer
53. Pedal-Operated Banana Fibre Extractor

Manufacturing Industries

54. Salt-lick for Cattle
55. Low-cost Soap
56. Chalk from Lime

House Construction Industries

57. Sun-dried Mud Bricks
58. Stone Block

Biomass-Based Occupations

59. Sericulture
60. Mushroom Cultivation
61. Bee Keeping
62. Nursery Raising

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ENERGY, EMPLOYMENT, AND RURAL DEVELOPMENT IN THE MOUNTAIN AREAS OF INDIA

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ENERGY, EMPLOYMENT, AND ALLOCATION OF TIME

Energy consumption and its impact on employment can be studied along several lines. Though the linkages between these two variables are reasonably clear, there are several sectors in which the relationship appears more direct, as in the case of industrial activity where technology is the major determinant of employment. Furthermore, in the rural and relatively unorganized developing countries, the lack of proper markets and the preponderance of household production over organized industrial production necessitates careful analysis of this complex set of linkages.

In a publication explaining the role of energy in household time allocation for production and consumption activities, this author investigated these relations, differentiating between commercial and noncommercial forms of energy (Pachauri 1983). The explicit inclusion of noncommercial energy becomes crucial in a study of this subject, given the fact that energy is increasingly scarce in much of the developing world, and households are having to devote more time to collecting fuelwood, animal dung, and other fuels for household consumption. Nowhere is this problem more acutely evident than in the mountainous and sub-mountainous areas of the Himalaya and the Hindu Kush ranges.

Production within the household and allocation of time, as published by this author, are summarized by the following relationship:

$$p_i X_i + w\, t_i + (w\, t_{in} + p_c E_{ic}) = S$$

Where

X_i = the quantity if the ith good purchased for consumption by the household

P_i = price of good X_i

t_i = input of time required for good X_i

w = average wage rate of household

t_{in} = time spent in collection of noncommercial fuels for X_i goods

p_c = price of commercial energy

E_{ic} = quantity of commercial energy consumed for X_i goods

S = total potential income of the household if all available hours spent in earning wages

When the reallocation of time resulting from a change in any one variable is interpreted, it is evident that an increase in the time allocated for collection of noncommercial fuel, such as t_{in}, results in a decrease in production of wage goods and other market activities. The increase in energy scarcity leads to a spiral effect in which the household sinks deeper into poverty with its lowered earnings and faces increased hardship because of difficult access to fuelwood or other energy resources. Programs and schemes dealing with these situations must, therefore, address the challange of breaking the spiral at the appropriate stage so that the household can sustain its productive activities.

ENERGY AND AGRICULTURAL EMPLOYMENT

The demand for energy in agriculture is growing with increased mechanization, irrigation, and use of fertilizers, all of which directly or indirectly require larger inputs of energy. This is particularly the case with the Green Revolution, which has largely been experienced in the plains. Whether these higher energy inputs are initially labor-saving or labor-demanding in mountain agriculture is not clear, since few studies have been carried out. However, going by evidence from other regions, some facts can be gleaned.

In a recently published study, Chaudari and Das Gupta analyzed the growth of agricultural output and inputs in Punjab, and found that agricultural output rates were constantly ahead of labor input rates, indicating that increases in output were preceded by increases in land, labor, and capital (Chaudari and Das Gupta 1985). There is some evidence of labor being displaced with larger inputs of capital and energy at the margin due to the technologies employed in Punjab, shown by the fact that land per worker declined while capital per worker and per hectare increased during the period covered. Modernization of mountain agriculture may thus initially have a positive effect on labor demand. An intensification of techniques using greater capital and energy is unlikely to result in any significant displacement of labor because agriculture in the mountain regions of South Asia is still remote from the modernization process that has taken root in the plains.

PERSPECTIVES ON NON-FARM EMPLOYMENT

Even more significant is the analysis of rural non-farm employment in the villages, since the constraints in the expansion of acreage and the low income levels of mountain farmers require that employment generation extend beyond agricultural activities. In a study carried out at the Asian and Pacific Development Centre, Kuala Lumpur, Mukhopadhyay and Chee investigated rural employment in the non-farm sector in the countries of the Asia and Pacific region (Mukhopadhyay and Chee 1984). Their work supports the fact that the concept of total employment is rooted firmly in the model of allocation of time.

Typically, macro-economic estimates of rural non-farm employment derived from statistical data bases underestimate the extent of such employment. Mukhopadhyay found that in Bangladesh, while the residual for rural employment from broad macro-estimates was only 5.7 percent (determined by subtracting the actual employment in all other sectors from the total employment figures), this figure was as high as 46 percent on the basis of microstudies of time allocation. In the Phillipines, she reports that a quarter of all rural labor and about 50 percent of the female rural labor can be identified as non-agricultural. This figure applies only to non-farm households, but when the non-farm labor of farm households was added, the author found more than half of all rural agricultural labor time is spent on rural non-farm employment. It should be emphasized that macrolevel policies derived from national aggregated data are likely to be misleading, since a number of the non-farm productive activities which are of vital importance in economic development at the decentralized level are not specifically taken into account when planning at the national level.

Mukhopadhyay also deals with the problem of segregating employment data for the rural non-farm sector in India from available statistics, because data on village industries and modern small-scale industries located in urban areas are not separated. There is also the unaccounted production that takes place in households, which is never included in official statistics. Mukhopadhyay estimated that the output generated in India during 1980 to be approximately Rs. 88 billion for the rural non-farm sector, Rs. 580 billion for the modern small-scale sector, with a total employment of about 44.18 million.

The category of rural non-farm employment includes such activities as manufacturing, construction, trade, commerce, and other services. Agriculture-related activities, such as food processing, appear to be the most dominant activity in several countries, but other forms of manufacturing such as textiles and handicrafts are also important.

FOREST ENERGY, FORESTRY, AND EMPLOYMENT

Forestry-related activities are a particularly relevant form of employment in the mountain regions, yet not many studies document the changes that have taken place in employment dependent on forest and forest-related activities. One study evaluates changes in the work force that have taken place in two densely populated forest districts of Karnataka (Nadkarni and Samuel 1985). The authors looked at changes in population, labor force, and forest and forestry-related activities. The study shows that the work force in the primary forest sector has been decreasing, but this is only a small part of the work force in the total forest sector. In North Canara, only 5.7 percent of the males and 4.0 percent of the females were enagaged in forest and forest-based activities in 1971. In the same year, the secondary forest sector accounted for 67.7 percent of the work force in North Canara and 77.5 percent of the male workers in Shimoga. In both areas, the female workers were a growing percentage of the work force. Further, the authors show that not only does deforestation lead to a tendency towards lower employment potential within non-farm activities, but it also leads to a reduction in forest-related employment, of which the largest effect would be on secondary forest activities. Based on the fluctuations and changes observed, the major brunt of this effect is on the female work force.

Some of the linkages and cause and effect relationships involving all these variables are shown in Fig. 1. In this figure AB represents the energy budget line for the household, which includes expenditure on commercial energy forms as well as the opportunity cost-based expenditure on noncommercial fuels. In the lower quadrant of this figure is the physical quantity of fuelwood collected as a function of time spent on collection, Et_{in}, which shifts from WW' to a lower level W_1W_1' after deforestation (Pachauri 1983).

The preceding analysis indicates that merely accounting for formal employment as recorded by official statistics is not adequate for studying rural development and employment. Since a large share of employment is in the form of non-farm activities, rural development and employment must focus on the forces that influence the activities of the rural household. The role of women and the effects of various factors on the allocation of their time is a central part of this question.

FEMALE LABOR AND WELFARE

Sufficient evidence indicates, at least in India and other parts of South Asia, the burden of rural poverty is disproportionately high in its impact on women. This is seen in the daily food intake of the members of the household, which is overwhelmingly biased against women. It was found that for an agricultural household in Kerala, a housewife's caloric intake, even when both husband and wife are employed as agricultural workers, is considerably lower than that of the husband (Gulati 1978). In a study carried out in Bangladesh, it was found that the caloric intake for females was considerably lower than for males (Chen et al 1981). This observation is valid even when differences in body weight and nutritional requirements between the sexes are taken into account. One can hypothesize, therefore, that energy scarcity leads a vicious cycle of effects. Women and children have to travel long distances to collect fuelwood and therefore expend larger portions of their time on this activity. This reduces the extent of time that they can participate in household productive activities, resulting in a drop in household earnings. This is further accentuated by the increased scarcity of forest products on which several productive activities are dependent. With the reduced earnings, there is a reduction in caloric intake for the household, already at a subsistence level of living, leading to a disproportionately high reduction in the nutritional intake of the housewife. With a lowered caloric intake, the housewife suffers a further reduced level of work output and spends less time on productive work and fuelwood or related energy collection activities.

This cycle becomes more acute as each of these conditions becomes more severe. The availability of energy is, therefore, a major determinant of the economic well-being and employment patterns of rural mountain households. More importantly, the increasing female drudgery and lower nutrition lead to lower productivity even when the actual number of hours worked does not decline.

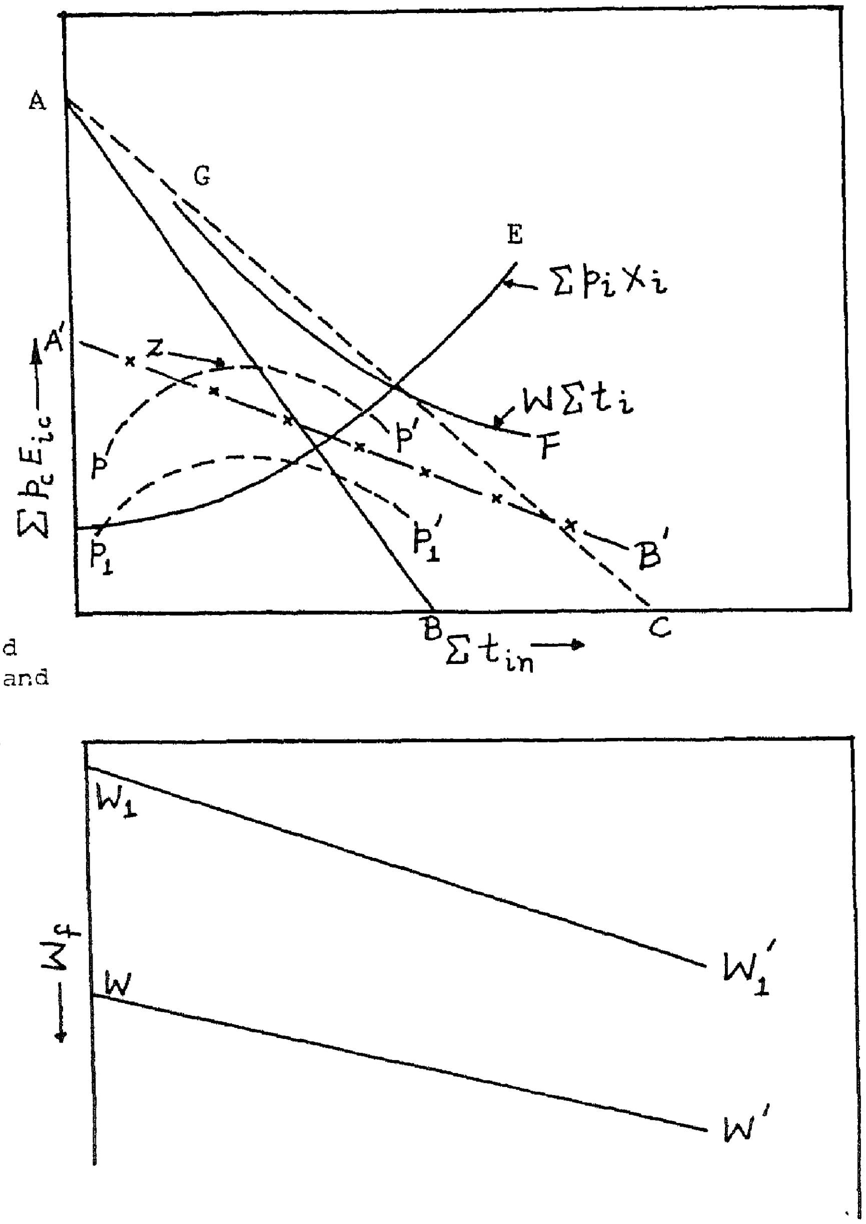

Figure 1

A model of household energy consumption and production.
Note: Not to scale.

AB - Energy budget line before deforestation
A'B' - Energy budget line after deforestation
DE - Money spent on market goods ($\Sigma p_i X_i$) before deforestation
FG - Opportunity cost of fuel collection ($W \Sigma t_{in}$) before deforestation
WW' - Fuelwood collected for time Σt_{in} before deforestation
$W_1 W_1'$ - Fuel wood collected for time Σt_{in} after deforestation
pp' - Production function of goods & services for household consumption before deforestation
$p_1 p_1'$ - Production function of goods & services for household consumption after deforestation

RESOURCE ALLOCATION FOR RURAL ENERGY PROJECTS

Most programs for rural development concentrate on agriculture. This is understandable in view of the differential between population growth and agricultural output, and the history of famines in this region. However, a concentration on agriculture alone may not optimize overall benefits for the community. The effect of energy on agricultural employment, therefore, needs to be investigated within a broader framework which incorporates more than these two variables.

In general, the resources allocated for agricultural development are directed at projects that use natural resources in the area which are considered to be unutilized or underutilized. Frequently, resources identified as unutilized in remote areas are actually limited in their development potential. Allocation of funds, therefore, does not yield commensurate returns, merely fulfilling weak targets and incorrectly identified goals without long-term benefit to the community. For example, study following a number of small irrigation projects in India would show that they have not provided the expected benefits. These investments, if undertaken in isolation, often do not lead to greater employment generation or a significant increase in output. The development of resources has to be planned and viewed in the overall context, and not necessarily tied in with the development of a single sector, such as agriculture. Government departments are largely biased in favor of inputs in the form of final outlays for specific schemes, whereas much greater benefit can be derived from the provision of technology, technical knowledge, or manpower development, using the same or even smaller financial resources.

The vital area in which major gaps exist in development programs is the dissemination of relevant technologies. The Green Revolution in India has been confined to the plains of India, using technology developed years ago. Given the importance of energy inputs for various activities, the need for innovations extends beyond farming practices and should cover the whole range of use of renewable sources of energy. These technologies require propagation, and therefore deserve special attention.

BIOGAS PLANTS

In the lowlying areas of the Himalaya and the Terai regions, biogas plants can be used for extensive periods during the year. The Tata Energy Research Institute (TERI) developed a shallow solar pond-assisted biogas plant which makes it possible for this technology to work more or less year-round even when the ambient temperatures reach low levels. The involvement of local communities and the setting up of decentralized organizations to service such a program are critical. The establishment of biogas plants would certainly ease the burden on the forests in lowlying areas where population densities are generally high. There is potential for employment generation during the construction and establishment of these plants and their subsequent maintenance.

IMPROVED *CHULAS*

The efficiency of energy use by cookstoves used in the mountainous areas of northern India is generally low, and a large-scale program for propagation of improved stove designs has not been successful. This technology cannot be justifiably imported from large towns in the area, but requires development of local knowledge and infrastructure. In the Kashmir and Ladakh regions, the traditional *bukhari* stove, which is used intensively during winter months, could be used with increased efficiency. This can be brought about through very simple improvements in construction and design. Any investment, if implemented with the involvement of local communities, would be worthwhile on the basis of savings in forest resources and in the related benefits of reduced siltation and denudation from their current levels.

SOLAR HEATING

Solar heating is economically viable and can be used directly for a large number of applications such as water heating, space heating, and crop drying. Significant improvements in dwelling conditions are also possible through the use of improved insulation in buildings and the use of large-scale passive solar heating. These devices can be produced by local industry, leading to increased rural employment.

HYDROPOWER

Traditionally, grinding and milling operations were carried out through the use of watermills. These are vanishing in most of the mountain areas and are being replaced by electric and diesel devices. These technologies are not economically suitable given the cost of centralized power supply in remote areas and the growing dependence on diesel fuel imports. Unfortunately, subsidies of electricity and diesel fuel have obscured the uneconomic nature of these forms of energy. In addition, there is an institutional gap at the local level which has resulted in suitable sites for hydropower being exploited at a sub-optimal level. Local problems in generating electricity on a decentralized level have also acted as barriers to the spread of small hydropower.

The examples given above are purely illustrative and would require a fresh and innovative approach in energy planning at a decentralized level. Whereas each of these schemes would require investments of physical capital and the development of human capital through training and education, the benefits are likely to substantially outweigh the costs.

In the formulation of the Seventh Five-Year Plan, some of these problems were taken into account. Under the Special Area Development Programs, the Plan calls for a Hill Area Development Program, incorporating many of the points referred to above. The Plan discusses the basic needs of hill people and has suggested a set of policies regarding energy, fuel and fodder supply, drinking water supply, health care, and education. The Plan has been conceived as a comprehensive set of actions which would bring about improvements in the environment. The Hill Area Development Program focused on beneficiary-oriented schemes during the earlier plans, but in the Sixth Plan Period, ecodevelopment was emphasized, without appreciably changing the general content of the Plan.

It remains to be seen whether the Seventh Plan will make a major departure from the past, and whether some of the institutional issues that are so crucial to the success of planning in these regions will be tackled in a satisfactory manner.

CONCLUSIONS

This analysis is purely exploratory and is based on studies done in the general subject area. There is little direct empirical evidence available on the mountain regions of India from which definite conclusions can be reached regarding the nature of energy, employment, and economic development in the rural areas. Nor can direct conclusions be made regarding the specific directions of policy interventions and programs required to foster the development of these regions.

On the basis of the evidence produced above and a discussion of the concepts explored, some tentative conclusions useful for implementing a suitable plan of action for the development of rural societies in the mountain regions can be made, focusing on energy development. The following points summarize the issues discussed:

1. The primary effect of energy shortages in the household sector is on the allocation of time for production. Energy scarcities result in a drop of household productivity, which normally dominates economic activity in mountainous rural areas.

2. While production and employment suffer from the reallocation of time for productive work, a further and more serious effect is produced with depletion of forest resources which provide the major raw material and capital inputs for non-farm activities.

3. Agriculture in the mountains has still not been modernized. While technological changes in agriculture in the plains show evidence of being labor-saving, this is unlikely to be the case in most mountain regions of India. Thus, with modern inputs, agricultural output could increase substantially, leading to higher incomes and improved economic well-being of these societies. At higher levels of income, technological change becomes more acceptable. It is entirely possible that with modernization of agriculture, improvements in the efficiency of energy-using devices, such as *chulas* and *bukharis* would be seen. This could also lead to the adoption of technologies which would result in the harnessing of local and renewable energy resources.

4. Energy and overall development planning in the mountain regions should incorporate investing in new technologies to harness local energy resources. The cost advantage of local energy resources over centralized power supply is currently obscured by the practice of subsidizing commercial energy.

5. The availability of power and energy would improve the general well-being

of households suffering from fuel scarcity. It would also provide productive employment in the form of small industries and improved agriculture which would result from the introduction of decentralized energy production. Incomes of the communities would naturally increase over time.

6. The availability of technologies for harnessing renewable forms of energy provides an opportunity for bringing about a second Industrial Revolution in rural areas. Since the introduction of these technologies would require the establishment of necessary skills and related industries for manufacturing and maintenance, employment potential of this strategy is enormous.

7. The capital-intensive nature of centralized power generation and the burden of oil imports limit the large-scale spread of consumption electricity from centralized sources and the large-scale use of petroleum products. Hence, the denudation of forests and their downstream effects will continue unabated unless the efficiency of energy use in the mountain areas is improved and renewable forms of energy are harnessed for local consumption.

8. This strategy would improve the role of women and the weakest members of rural societies. The key to development lies in improving their nutritional and social status, since a large share of productive activity takes place in the household. These developments would also have a favorable effect on education for children and the development of human resources.

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Section 3 : REGIONAL ENERGY STATUS

ENERGY SCENARIO IN THE STATE OF JAMMU AND KASHMIR

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INTRODUCTION

Energy resources hold the key to the economic development of any region. Their availability accelerates growth and development and their non-availability retards development. This paper attempts to present a brief status report on the availability of energy resources and their existing and projected consumption patterns in the region of Ladakh, Jammu, and Kashmir. The non-availability of reliable time series data offers a serious constraint in presenting a realistic picture of the energy scenario in the state. Nonetheless, an attempt has been made to present a realistic picture of the energy resources of the state and the problems concerning their developent.

Physiography and Geology

The development of energy resources cannot be perceived correctly unless viewed in the context of physiography and geology. Jammu and Kashmir lies between 32°15'N to 37°5'N latitude and 72°35'E to 80°20'E longitude. It has a total area of about 222,000km^2. Its population, according to the census of 1981, was 5.95 million (Census of India 1981). Nearly 80 percent of the total population is rural and depends largely on primary economic activities--agriculture and forestry.

Geologically, the state has rock formations from the Archaen to the Cainozoic Eras (Wadia 1981). The geological structures are not favorable for fossil fuels. However, in the rocks of the Carboniferous Age, coal seams yielding brown coal and lignite have been found in Kalakot (Jammu Region), and Pulwama and Baramulla (Kashmir Region). Peat also occurs in patches in the alluvium of Jhelum and in the swampy ground of the upper reaches of the Kashmir Valley. Dried peat bricks are used as fuel. Peat is also applied in the fields as manure.

Physiographically, three distinct regions of the state can be identified: Jammu, Kashmir, and Ladakh. These are also distinct cultural regions. The Jammu region, comprised of southern alluvial plains, constitutes part of the Great Plains of India and resembles the landscape of Punjab. To the north of the plains lies the Kandi (undulating) tract, the ranges of the Siwaliks, and the Pir-Panjal Range. The Siwaliks of Jammu have an average altitude of 600 meters, while the Pir-Panjal which makes a water divide between Tawi and Chenab Rivers has an average elevation of 2500 meters above sea level (Raza et al 1978). The Chenab River, generally running along the strike between Pir-Panjal and Zanskar mountains, cuts a deep gorge through the northern parts of the Jammu region.

The Kashmir Valley of Kashmir is of

recent geological origin. It is a synclinal basin with the character of an enclosed vale, being surrounded by an unbroken ring of young folded mountain ranges with Pir-Panjal in the south and the Zanskar range in the north. Having been the scene of simultaneous operation of the complementary processes of deposition and sub-areal denudation, the surface features of the valley show the inextricable juxtaposition of both (Raza et al 1978). The Pir-Panjal forms a formidable barrier on the south and southwest, separating it from the Jammu region; the Great Himalaya and the Zanskar ranges shut it off from the frostbitten plateau desert of Ladakh and Baltistan. The region is drained by innumerable streams and rivers but mainly by Jhelum (Vitasta), Sindh (a tributary of Jhelum), Rembiara, Lidder, Dudganga and Harwan.

Ladakh constitutes the northernmost physiographic cultural and administrative region of the state. It includes Kargil, Zanskar, Rupshu, Nubra, Aksai-Chin and Leh. Ladakh is a vast arid tableland located at an average height of 4000 meters above sea level. It is mostly formed of mechanically weathered rocks and granite dust and is completely bereft of forests and pastures.

Climatic Conditions

The state of Jammu and Kashmir is situated in sub-tropical latitudes, but owing to high altitudes and snowclad peaks, the predominant climate has strong mountainous and continental characteristics of the temperate latitudes.

The southern part of Jammu region, being for the most part continuous with the plains of Punjab, is marked for its monsoonal climate. It is very hot during summer and equally cold in winter. The severity of winter is accentuated in areas of high altitudes because of heavy and frequent snowfall. The rainy season in Jammu region lasts from mid-June to September. Nearly 80 percent of the region's average annual rainfall is recorded during this season.

The Valley of Kashmir has a temperate continental climate, characterized by marked seasonality. In fact, the genesis of Kashmir weather is intrinsically linked with the mechanism of weather in the Indian subcontinent in general. Nevertheless, the Valley, being surrounded on all sides by the Himalaya ranges, has a modified sub-tropical climate. It has a fairly long spring stretching from March to the middle of May. Springs are fairly cold and wet, the mean monthly temperature in April being only about 16°C. The summer season, locally called *grishm*, lasts from June to August (Raina 1971). The region experiences a high degree of insolation in this season because of the rarified atmosphere at high altitudes, which leads to the steady melting of glacier ice. This improves the discharge of rivers and the consequent efficiency in the generation of hydel power. It is during this period that the peak generation of hydel power is recorded and load shedding is minimum. September and October are the months of autumn, locally know as *harud*. These months record the maximum range of temperature. Although the cold season or *wand* and *shesur* lasts from mid-October to February, its intensity is experienced from mid-December to the end of January which is locally termed as *chilla-kalan.* Heavy snows fall in the mountains during this season and occasionally in the Valley also. The mean minimum temperature in January remains below -3°C, often reaching as low as -10°C. During this period the Kashmir Valley receives rains from the western disturbances (Temperate Cyclones). Winter rains are, however, associated with snow in January, February, and early March.

The Valley received an unprecendented heavy snowfall of over 200 mm in 24 hours on 25-26 December, 1985. For nearly three weeks both the maximum and the minimum temperatures remained below the freezing point. During this period, the need for power is greatest but the supply is minimum because of the sharp decline in the flow of water. Since coal as a source of energy is not available locally, the axe falls on fuelwood which is extensively used, consequently leading to deforestation as will be observed later.

The climate of Ladakh and Zanskar is very dry and cold. In winter, the rivers freeze and the temperature often goes below freezing point, the mean minimum reading as low as -10°C at Leh and -40°C in Dras. The skies are generally clear and insolation intense. Winds, however, blow with steady speed and are a potential source for generating wind energy. Day temperatures in summer rise to 40°C which becomes unbearable. The Indus, Shyok, and other valley regions are extremely warm in summer. The atmosphere of the Leh Valley is remarkably transparent and the heat of the sun, which can be harnessed for the generation of solar energy, is intense.

Floristically, the state is divided into three regions: alpine desert flora of Ladakh, predominantly temperate flora of Kashmir, and sub-tropical flora of Jammu (Kachroo 1985). Ladakh hardly receives precipitation except in the form of snow and frost and is characterized by xerophytic vegetation. Scrubby bushes constitute the major vegetational component of Ladakh, except in the more humid regions of Nubra Valley. The Kashmir region has distinct vegetation zones because of altitudinal change from 1350 meters to 400 meters above sea level: mixed vegetation of broad-leaved deciduous trees and conifers; conifer forest; white juniper, birch, and stunted birch; and alpine flora zones. The willow trees *conium maculatum* and *senecio vulgaris,* which are found extensively in Srinagar and among river and canal banks up to a height of 2600 meters are a recent introduction in the Valley. The sub-tropical belt of the Jammu region is dominated by broad-leaved forests, both deciduous and evergreen. Oak (deodar) and pine trees are found occasionally on the inter-Pir-Pinjal ranges. The foothills are dominated by *dodonaea* scrub and *sissoo.*

Demographic Characteristics

The population of Jammu and Kashmir, according to the census of 1981, was 5,954,009, which is slightly less than the population of the Union Territory of Delhi. During 1971-81, it registered an anual growth rate of 28.95 percent, which is much above the national average growth rate of 20 percent. Table 1 presents a synoptic view of some of the basic demographic characteristics of the state and its three regions

Table 1: Jammu & Kashmir State: Some Basic Population Characteristics - 1981

State/ Region	Total Population	% of total	Decadel growth rate 1971-81	Urban Total	Pop %	No. of towns	Rural Total
J & K	5954009	100	28.95	127877	21.47	56	4675238
Kashmir Div.	3134904	52.6	26.42	828009	26.41	23	2306895
Jammu Div	2717069	45.8	25.92	420579	15.47	31	2296410
Ladakh Div.	620953	1.6	24.85	30613	4.93	2	590340

Table 1: (Contd.)

State Region	Population %	Density of population	Total Working Population	Percent of Working Population		
				Primary	Secondary	Tertiary
J & K	78.53	59	30.08	62	6	32
Kashmir Div.	73.59	196	31.56	77	6	17
Jammu Div.	84.53	103	28.73	81	7	12
Ladakh Div.	95.07	5	44.78	73	5	22

Source: Census of India 1981

regions. The Kashmir Valley stands out as the demographic node of the state, containing 52 percent of its total population. Of the three regions, the Valley has the highest population growth rate, claims the highest gross density of population (which speaks for its land-carrying capacity), and contains over 60 percent of the state's total urban population. The state, however, has a weak economic base which is substantiated by the dominance of primary and tertiary sectors in its occupational structure.

ENERGY RESOURCES OF THE STATE: DEVELOPMENT AND CONSUMPTION PATTERNS

The resource base and socioeconomic structure reveal that the state is well-endowed with fuelwood and water resources; however, it is deficient in coal, petroleum, and natural gas. Of the energy resources used in the state, hydroelectricity, fuelwood, and kerosene are by far the most important. Together, they constitute 95 percent of the total energy consumed in the state. Presently 80 percent of the energy consumed in the state is obtained from fuelwood trees raised on farm embankments and from culturable wasteland. The consumption of electricity, kerosene, and LPG predominates in urban areas whereas rural areas depend largely on fuelwood. In the villages of Kandi or undulating hill areas, fuelwood constitutes up to 98 percent of the total energy consumed for cooking, heating, and lighting (Husain 1986). Although largely confined to the urban centers, electricity is the prime source of energy, particularly in Srinagar and Jammu--the summer and winter capitals of the state--where commercial and industrial activities are concentrated.

Fuelwood

The state has a wide variety of temperate and sub-tropical trees in its extensive forested areas, which cover nearly 30 percent of the total area. Most of these are used as fuelwood, but the principal among them are conifers and willows (Table 2). Twigs and branches constitute a very important source of energy, particularly in the rural areas of Jammu region. In four of the six districts of this region, twigs and branches are the dominant source of domestic energy and are acquired free of cost. Conifers (blue-pine and silver-pine) are the predominant source of fuelwood in the Kashmir region and in districts of Jammu region which have extensive use of fuelwood. In Srinagar district, twigs and branches, conifers, and willows are consumed in almost equal proportion. In the tropical parts of Jammu region, tropical trees like *banmusroo* and *kail* are also used as fuelwood.

Of the conifers used for fuelwood, silver-pine is most common. The blue-pine is valued more for its fine quality of charcoal. Because of its oil-bearing quality, it is also used as a source of domestic lighting in rural areas, particularly during winter.

It has been estimated, based on a pilot study, that the average annual consumption of fuelwood in the state amounts to approximately 26 million quintals. This pilot study covered 416 rural and 293 urban households from the Jammu and Kashmir regions, and was

Table 2: Spatial Consumption of Fuelwood in Jammu and Kashmir Divisions

District	Twigs branches	Conifer	Willow	Kikar	Hatab	Walnut	Poplas
Anantnag	36	40	21.2	0.4	0.3	-	-
Badgam	40	39.1	12.6	6.3	-	-	-
Baramulla	29.4	30.1	17.7	11.6	-	0.5	4.0
Kupwara	41.2	58.8	-	-	-	-	-
Pulwama	24.8	52.1	14.0	2.7	-	-	-
Srinagar	22.0	39.5	33.1	2.1	-	-	-
Doda	15.3	57.4	-	-	-	-	-
Poonch	77.0	23.0	-	-	-	-	-
Jammu	64.4	1.4	-	8.8	-	-	-
Kathua	73.8	10.2	-	-	-	-	-
Rajouri	44.2	50.2	-	-	-	-	-
Udhampur	69.3	16.9	-	-	-	-	-

Table 2: (Contd.)

District	Zangloo	Fruit trees	Banjm-naroo	Tali	Derek	Eucalyptus	Others	Total
Anantnag	-	-	-	-	-	-	1.0	100
Badgam	-	1.3	-	-	-	-	-	-
Baramulla	1.3	5.4	-	-	-	-	-	100
Kupwara	-	-	-	-	-	-	-	100
Pulwama	-	-	-	-	-	-	-	100
Srinagar	-	3.3	-	-	-	-	-	100
Doda	-	0.2	19.3	-	-	-	9.8	100
Poonch	-	-	-	-	-	-	-	100
Jammu	0.2	-	-	23.1	1.7	0.4	-	100
Kathua	-	1.9	2.0	3.1	-	-	9.0	100
Rajouri	-	-	-	0.8	-	-	4.8	100
Udhampur	1.3	-12.5	-	-	-	-	1.0	100

conducted in 1983. The study shows that in addition to firewood, which constitutes the single most important fuel for domestic consumption, cowdung, sawdust, dry-leaves, charcoal, soft coal, kerosene, and cooking gas are also used as domestic fuels. Of these, the consumption of kerosene and gas is confined primarily to urban areas. In the rural areas where firewood and its byproducts are the principal sources of domestic fuels, one or two members of each household spend a part of his/her working hours collecting dry firewood twigs, branches, dry leaves, and dungcake from forests, arable lands, wastelands, and pastures. No studies, however, are available to indicate the manhours rural households spend collecting fuelwood for domestic consumption.

It has been estimated in the same study that the per head consumption of firewood in the state is 3.8 quintals per annum with twigs and branches accounting for 1.6 quintals or 42 percent of this consumption. The per capita consumption of firewood in rural areas is 4.4 quintals per head per annum compared to 2.5 quntals per capita in urban areas. Twigs and branches constitute 2.1 quintals per capita per annum in rural areas and 0.4 quintals in urban areas.

Table 3 also highlights the fact that of the three regions, Kashmir has the highest fuelwood consumption, but its per capital consumption is lower than that of Jammu region, presumably because of its higher proportion of urban population. Of the total fuelwood consumed in the state, 42 percent (10.94 million quintals) is contributed by twigs and branches, and the balance of 15.10 million quintals is obtained in the form of wood from forests. Nearly one million quintals of dry leaves are also annually consumed as fuel in the rural areas of the state (Table 4). It is obvious that deciduous trees such as *chinar* (Nepal) and poplar, which shed their leaves in autumn, also play a role in the supply of fuel to the people of the state. The consumption of firewood and its byproducts as fuel by regions and districts is given in Table 4.

The combined per capita consumption of firewood in both urban and rural areas varies from a minimum of 0.8 quintal in Jammu to a maximum of 4.3 qunitals in Doda. In the rural areas, consumption ranges from 0.7 (Jammu) to 4.7 (Srinagar). The highest (5.5) and the lowest (0.1) per capita consumption of firewood in both urban and rural areas is higher in the Kashmir region. In the Jammu region the consumption of twigs and branches is more prominent. Table 4 further reveals that the consumption of dry leaves, charcoal, and sawdust as fuels is confined to the Kashmir region. About 80 percent of the charcoal is prepared from superior timber trees (deodar (oak), *badul* (silver-pine), spruce, and pines). Charcoal is used in *samewars* for preparing tea or heating water, and in *kangris* (portable earthen heaters). The urban poor also use sawdust for cooking and heating.

It is evident that at present, fuelwood is the most important source of domestic energy in the state. Massive use of fuelwood has led to excessive deforestation and consequent widespread encroachment on forest and pasture lands especially in the Narang Catchment, Daksum Valley, Gurez Valley, and the slopes of the Pir-Panjal.

Table 3: **Jammu and Kashmir State — Rural Urban Fuelwood Consumption Regionwise—1983**

Figures in thousand quintals

Region	Rural Population	Fuelwood consumption	Urban Population	Fuelwood consumption	Total Population	Fuelwood consumption	Share of each region to total %
Jammu	2297010	10101 90.59%	420059	1050 9.41%	2717069	11157	42.8
Kashmir	2306265	10146 83.06%	828099	2070 16.94%	3134364	12216	46.9
Ladakh	590340	2597 97.14%	30613	76.5 2.86%	620953	2673	10.3
Total	5193615	22850	1378771	3196.5	7472386	26046	100.00

Source: Census of India 1981, and field work by the authors.

This encroachment has accentuated the process of soil erosion. Although detailed investigations about the spread of eroded areas have yet to be made, it is so widespread and of such serious proportion that even a layman cannot fail to notice it. Under the increasing population pressure, farmers are extending cultivation even on vulnerable steep slopes, thereby making the ecosystem more fragile.

Forests which have been indiscriminately felled for fuel and timber are vital for the maintenance of ecological diversity, preservation of watersheds, prevention of soil erosion, moderation of climate, and provision of areas of aesthetic value for recreation. In brief, deforestation accelerates erosion and makes run-off more erratic, reducing availability of water and resulting in water pollution. This process may become irreversible, altering the environment so drastically that the ecosystem may loose its balance and resilience, making afforestation impossible, and reducing the scenic beauty and economic productivity of the areas until they become ecological slums. In this context, power development should be carefully assessed. If ecological balance is to be preserved and environmental degradation to be halted, then the use of forest as fuelwood has to be minimized and the development of other conventional and nonconventional resources of energy, such as hydel, thermal, nuclear, wind, solar, and biogas, should be accelerated.

Kerosene, Coal, Cooking Gas, and Cowdung Fuels

In addition to firewood and its byproducts, the state also consumes

Table 4: Per Capita per Annum Consumption of Wood and Its Byproducts as Fuel in Rural and Urban Areas (1983)

	Firewood			Twigs & Branches			Dry leaves		
District	R	U	T	R	U	T	R	U	T
Kashmir Region									
Anantnag	2.3	4.0	2.6	1.5	1.3	1.5	0.3	0.2	0.3
Badgam	1.3	4.5	1.9	1.6	0.6	1.4	0.3	0.8	0.4
Baramulla	2.8	4.8	3.2	1.6	-	1.3	0.3	Neg	0.2
Kupwara	3.4	5.0	3.6	3.0	-	2.6	1.6	Neg	1.3
Pulwama	3.1	2.8	31	1.1	0.3	1.0	0.1	0.1	0.2
Srinagar	4.7	2.3	1.9	2.0	0.2	0.6	0.1	Neg	Neg
Jammu Region									
Doda	4.3	4.6	4.3	0.9	-	0.8	0.1	-	Neg
Poonch	2.0	5.5	2.9	4.5	-	3.3	0.4	-	0.3
Jammu	0.7	0.1	0.8	1.3	0.1	1.4	Neg	-	Neg
Kathua	1.0	0.6	0.9	3.0	1.4	2.6	-	-	-
Rajouri	3.1	4.4	3.2	3.1	-	2.6	0.4	-	Neg
Udhampur	1.2	0.3	1.1	2.5	2.3	2.4	0.1	-	Neg

	Charcoal			Sawdust		
District	R	U	T	R	U	T
Kashmir Region						
Anantnag	0.3	0.1	0.3	0.4	1.7	0.6
Badgam	0.4	0.2	0.4	Neg	0.2	0.2
Baramulla	0.3	0.1	0.3	0.3	3.3	-
Kupwara	0.3	0.1	0.3	-	-	-
Pulwama	0.1	0.2	Neg	Neg	0.1	Neg
Srinagar	0.3	0.3	0.3	-	0.1	Neg
Jammu Region						
Doda	Neg	-	Neg	-	-	-
Poonch	-	0.2	0.1	-	-	-
Jammu	-	Neg	Neg	Neg	Neg	Neg
Kathua	-	-	-	-	-	0.2
Rajouri	-	-	-	-	-	-
Udhampur	-	-	-	-	-	-

Source: Directorate of Economics & Statistics, Planning & Development Department, Govt. of J & K, Pilot Survey, 1983 kerosene, coal, cooking gas, and cowdung as domestic fuels. Barring cowdung, which is consumed primarily in rural areas, the other three sources are used mainly in urban centers.

Kerosene is an important source of fuel, especially for cooking, but its consumption is strongly urban-centered. In the Kashmir region, Srinagar, which has over 19 percent of the state's total population, consumes over 67 percent of total kerosene supplied to the region (Zutshi et al 1985). The districts which are away from the capital cities of Srinagar and Jammu (Doda and Kupwara) have significant levels of kerosene consumption. On average, it has been estimated that the per head per annum consumption of kerosene in the city of Srinagar is about 19.8 liters, which is much higher than in the rural areas and more than double the consumption (8.7 liters) in the state.

Coal is not locally available and has to be transported by truck to the Valley from the Bihar coal mines. Consequently, due to its high cost, coal is used as fuel, particularly during winter by institutions such as army camps, factories, and educational institutions, and by the urban rich. Reliable figures are not available for the annual consumption of coal. In the University of Kashmir, 1200 quintals of coal are used in winter for *bukharis*--an indigenous device for heating rooms.

Cooking gas was introduced in the state in the late sixties. Its use, however, is limited to the principal cities. For example, in the Kashmir region, about 82 percent of gas consumer-connections are in Srinagar Municipality, while Jammu Municipality accounts for 79 percent of gas because of high capital costs of installation, confined to the upper strata (Alam et al 1985). Occasional breakdown of the transport system, particularly during the winter season, adversely affects the supply of gas in the Valley.

Seasonal Variations in Fuel Consumption

Seasonal variations in temperature lead to wide fluctuations in the consumption of domestic fuels. The consumption of fuel during winter is appreciably high, especially in the Valley of Kashmir and in the Kandi areas of the Jammu, Kashmir, and Ladakh regions. The impact of seasonality on the consumption of fuel is highlighted in Table 5.

The consumption of practically all the fuels almost doubles during winter. In the absence of an assured supply, which frequently happens particularly with LPG, kerosene, and coal, the people are subjected to severe hardship; during winter, the generation of power at the state hydel stations is also at its lowest.

Power Development, Consumption, and Potential

As pointed out earlier, power is the key to a high level of economic development. Its level of consumption in any country is a significant indicator of development. For instance, the U.S.A. claims a per capita consumption of 8,487 units per day. In sharp contrast, the Indian average per capita consumption is 133 units. In Jammu and Kashmir, it is only 93 units per capita per day. This is among the most backward states of India and will continue to stay as such unless adequate and early steps are taken to improve its power situation. The state has hardly any coal, and because of unfavorable geological conditions, the prospects of striking gas and petroleum are not promising. It has however, tremendous potential for hydel generation which has been inadequately tapped. By considering the status of water power development in the state, projected demand for power, as well as development potential for power, may be analyzed.

Table 5. Consumption Per Capita Per Annum

	Rural		Urban			Total	
	Summer	Winter	Summer	Winter		Summer	Winter
Firewood	1.6	2.8	0.8	1.7	1.4	2.4	3.8
Dry leaves	-	0.2	-	-	-	0.2	0.2
Charcoal	0.1	0.1	-	0.1	0.1	0.1	0.2
Sawdust	-	0.1	0.1	0.3	0.1	0.1	0.2
Kerosene (ltr)	1.6	2.4	9.5	10.3	3.9	4.8	8.7
L.P. Gas (kg)	-	-	2.3	4.6	0.7	1.3	2.0
Cowdung	0.4	0.9	0.1	0.2	0.3	0.7	1.0

Source: Survey of Renewable Energy Resources and Requirements in J & K, University of Kashmir

The three perennial rivers--Indus, Jhelum, and Chenab--and their tributaries which drain the state, open immense opportunities for the generation of hydroelectricity. It has been estimated that these rivers provide theoretically a potential of 13,000 MW of hydel generation. Because of faulty planning and priorities, only a fraction of this potential has so far been utilized which can be observed in Table 6. The importance of hydroelectricity is highlighted by the fact that 270 MW of hydel power at 6 percent load factor for one year is equivalent to 340 tons of diesel oil (Kumar 1985). On this basis, the above theoretical energy will be equivalent to 20 MT of diesel oil.

The total generation of hydel power in the state amounts to 168 MW in the summer season, which drops to 121 MW in the winter season. In addition, the state gets 60 MW from the northern grid which, with the help of capacitors, is raised to 75 MW. These sources of power together supply on average 956 MU of power per year which is almost half the actual demand for power in the state. It can be observed from the following figures that during a short spell of three years the gap between demand and supply has increased manifold from 19 MW in 1981 to 187 MW in 1984.

Lack of adequate power supply has retarded the growth of industrial, commercial, and agricultural development in the state. Power supply is rationed throughout the year and particularly during the winter season,

Table 6: Jammu and Kashmir State: Generation of Hydel Power (1984-85)

Division	Installed	Effective Capacity MW		Summer Winter
		Summer	Winter	Difference
A - Jammu				
(1) Chenei HEP	25	20	12	8.0
(2) Kalakot Thermal	21.4	4	4	-
(3) Other Small Stations	3.0	2	1	1.0
Total - A	49.9	26	17	5.0
B - Kashmir				
(1) L. Jhelum J. P.	105	105	65	40.0
(2) U. Jhelum Stage I	22.62	22	17	5.0
(3) Canderbal	15.0	12	10.5	1.5
(4) Morhra	9.0	7	7	-
(5) Bemina & others	6.0	-	4.5	-
Total - B	157.6	146.0	104.0	-
Total A + B	208.1	168.0	121.0	47.0
C - Imports				
State share from B.B.N.M.	-	27.0	27.0	-
Total A + B + C	208.1	195.0	148.0	47.0

Source: Digest of Statistics, Jammu & Kashmir State, 1983 - 84

when in Srinagar no part of the city gets more than 8 hours of power supply in 24 hours. On account of this restricted supply of power in the state, and especially in the Valley, no major industry except Hindustan Machine Tool could so far be attracted despite packages of incentives, such as tax concessions and rent-free land, which the state government has offered to provide. If this gap in demand and power supply is allowed to grow, the state will perpetually remain one of the least developed states of India (Mujoo 1985). It is expected that the state may begin to receive over 150 MW of power from Salal early in 1987. If this happens, the power situation in the state will be relieved to a certain extent. The Dulhasti project has not gone beyond the investigation stage, and is not likely to be completed before the end of the century. The state government is also contemplating installation of a standby diesel power generating sets of 100 MW in the Srinagar region, to overcome the

Table 7: Electricity Demand and Supply by Seasons

	SUMMER			WINTER		
	DEMAND (MW)	SUPPLY (+)	DIFF. (-)	DEMAND (MW)	SUPPLY (+)	DIFF. (-)
1980-81			- 24			- 19
1983-84	271	168	- 308	107	121	- 187

acute scarcity of power during the winter season in the Valley.

Hydel Power Projects Under Investigation and Execution

Although theoretically the potential for power development seems to be colossal, a realistic estimate of the potential for power development reveals that in the next 14 to 15 years, if financial resources are made available, 3208.64 of hydel power MW can be installed in the regions of the state as shown in Table 8 and detailed in Table 9.

Table 8: Regions Expected Installed Capacity

Regions	Expected Installed Capacity
State	3208.64 MW
Kashmir	259.80 MW
Jammu	291.00 MW
Ladakh	39.56 MW

It may be noticed that most of the projects which have been taken up for investigation and execution in the Ladakh and Kashmir regions are either medium- or mini-order projects which can be implemented within the stipulated period of time if funds are made available. In contradiction, most of the projects in Jammu are large-sized and highlycapital-intensive. The power development programs in the early stages of the Plan periods were installed because of the emphasis of state planners on major hydel projects, such as Salal and Dulhasti, which if completed would have yielded over 500 MW of power. The Planning Commission could not allocate requisite resources for these projects.

In order to reduce backwardness and accelerate economic development, resources must be found to implement these power projects which are either in advanced stages of investigation or execution.

Power Supply and Demand Projections

The state of Jammu and Kashmir has a weak statistical base. Time series data are not available for scientific projection of power demands for the next 15 to 20 years by the various sectors of the economy. Even the present consumption figures for the various sectors are not available and have been disaggregated in accordance with the growth estimate of power

Table 9: Hydel Projects Under Investigation

Region	Installed Capacity	Energy Million Units
A - Ladakh Region		
1. Iqbal Rridge Hydel P.	3.75MW	under execution
2. Igo-Phey	5.60MW	38.65
3. Nattayan	0.45MW	0.25
4. Shakerchiktan	0.26MW	1.56
5. Timbis Kunur	0.20MW	1.20
6. Haftal	1.00MW	2.17
7. Kumdock	0.10MW	0.60
8. Dum Khar (micro)	2.00MW	2.20
9. Tungate	.10MW	0.60
10. Bung-Dong	.20MW	1.20
11. Thusgam barso	.20MW	1.20
12. Marpocho	.20MW	1.20
13. Hanu	.75MW	1.50
	11.06MW	48.65
Medium Hydel Projects		
1. Panikher Parkchak	9.5MW	21.19
2. Chotak Project	9.5MW	21.19
3. Dumkhar	9.5MW	21.19
Total	28.5MW	63.57
Grand Total	39.56MW	111.71

B - Kashmir Region	River Stream	Installed Capacity
1. Upper Sindh Hydel Project Stage II	Sindh	10.5 MW
2. Nunwan-Batkote	Lidder	22.6 MW
3. Shitkari-Kulan	Sindh	84.0 MW
4. Boniyar	Boniyar	4.8 MW
5. Hirpora	Rambiara	9.0 MW
6. Athwatoo	Madhumati	7.5 MW
7. Barenwar	Doodganga	2.0 MW
8. Tangmarg	Ferozpur Nallah	2.6 MW
9. Mutchill		
10. Asthan	Gurez Nallah	1.0 MW
11. Keran	Keran Nallah	0.6 MW

B - Kashmir Region (Contd.)	River Stream	Installed Capacity
12. Wangat	Wangat	1.5 MW
13. Ardow Stage I	Lidder	7.5 MW
14. Ardow Stage II	Lidder	3.0 MW
15. Laripora	Lidder	2.5 MW
16. Erin	Erin	3.0 MW
17. Pahalgam	Lidder	3.0 MW
Total		239.8 MW

C - Jammu Region	Installed Capacity	Location/Investigation Agencies
1. Gyspa	222 MW	NP/HP
2. Bardung	54 MW	NP/HP
3. Seli	87 MW	NP/HP
4. Roli	295 MW	NP/HP
5. Kirtha Naunatoo	750 MW	J&K/J&K
6. Naunatoo-naigad	400 MW	J&K/J&K
7. Dul-Hasti	390 MW	J&K/CWC
8. Ratlee	170 MW	J&K/CWC
9. Bagliar	220 MW	J&K/CWC
10. Sawel Kot	400 MW	J&K/CWC
11. Bursar	275 MW	J&K/CWC
12. Pukhul	325 MW	J&K/CWC
13. Salal	354 MW	J&K/CWC under execution

demand projected by the state government. These points may be borne in mind while reading Table 10, giving existing and projected power consumption in the state by 2000 A.D.

The energy planners of the state have projected a fivefold increase in the consumption of power, excluding domestic consumption, from 956 MU in 1984 to nearly 5000 MU in 2000 A.D. The highest rise in demand has been projected in the industrial sector on the assumption that a high rate of industrial growth is inevitable to cope with rising unemployment. Industrial growth will be dependent on the availability of power. The domestic sector is also likely to register phenomenal growth if other sectors develop along the lines projected above. These projection figures make it clear that economic well-being and future prosperity are inextricably tied with massive power development.

Nonconventional Sources of Energy

The use of nonconventional sources of energy such as solar energy, biogas, wind energy, and geothermal energy is still in experimental stages. It may be noticed from Table 11 that in the

Seventh Plan, allocation for the development of nonconventional sources of energy is meagre.

Solar energy. Solar energy is perennial, available free, and convertible to most other forms of energy. It is free of load shedding and climatic discomfort. It has the further merit of being a dispersed energy source which every household and every village can use, especially in Ladakh where it holds distinct promise because of high insolation. A recent study reveals that even if the solar photovoltaic (PV) array and acessories are supplied free of cost, the cost of batteries alone would make the cost of energy not less than Rs. 2.18 per kWh (Mujoo 1985).

In Jammu and Kashmir, the Department of Nonconventional Energy Sources (DNES), Government of India has agreed to electrify a village each in Zanskar and Bani (Ladakh), both situated in the far-flung areas of the state, by providing solar PV arrays with batteries of 12 kW and 1 kW respectively (National Paper India 1981). If this project succeeds, and if in view of worldwide declining prices of solar PV cells the Department of Nonconventional Energy Sources agrees to assist and give further subsidies, the state of Jammu and Kashmir should be able to have a generating capacity of almost 150 kW of solar electricity by 1990.

Wind energy. The wind speed data published by the Indian Meteorological Department and analyzed at the National Aeronautical Laboratory, indicates that in Ladakh and parts of Jammu and Kashmir Divisions, the average wind energy density is more than 3 kWh/m^2 on an annual basis. Thus, conditions are conducive to the development of windmills and systematic efforts are underway for their development (Kumar 1985). Under the National Project for demonstration, 25 wind-operated water lifting pumps for irrigation and other uses were allotted to this state. These pumps are designed to operate at cut velocity of 2.5 N/sec and give a discharge of about 20,000 liters/hour. In all, 16 wind pumps were received from the manufacturers, but only one could be installed in Tikri (Udhampur) for providing water to a forest nursery.

Biogas. Biogas produced mainly from cowdung, night soil, and poultry droppings can be utilized as a fuel for cooking, lighting, running diesel engines and for generating electricity. One well-known advantage of this technology is that cowdung and other wastes are converted into enriched manure in the digester after the generation of gas. The use of biogas in the villages also helps in improving sanitary conditions and checks environmental pollution, besides reducing drudgery and improving health conditions of rural people.

In Jammu and Kashmir, family-size biogas units are being popularized by the Agriculture Production Department. The costs of these units are fully covered through DNES subsidies and bank loans. The Department of Power is now focusing on the commissioning of large-sized community/institutional biogas plants (Kumar 1985). A few of them are likely to be installed during the course of the Seventh Plan Period.

In Srinagar, a weed gassification project is also under consideration. This is an

Table 10: **Present and Projected Consumption of Power by Sector—1984 - 88, 1989-90, 1990 - 95, and 1995 - 2000 A. D.**

Million Units

Sectors	Power Consumption 1984-85	Projected Consumption	Power increase		Projected Rate in 2000 AD over 1984 - 5 level of Consumption	Growth in Percent
		1989-90	1990-95	1995-2000		
Total	956.0 MU				4834.14	
Agriculture	122.0	172.5	266.4	436.0	134.0	10-15
Industry	250.0	502.8	1015.6	2392.8	2142.8	12-20
Commerce	80.0	150.6	379.3	770.2	690.2	10-11
Sevage'Public Water Supply & Municipal Corporation	90.0	137.5	242.3	478.3	388.3	12
Public Lighting	12.0	23.49	41.98	89.04	72.04	12
Bulk Consumers						
Commercial	180.0	262.0	421.90	745.50	665.50	10
Non-Commercial						
Transport	-	61.03	235.30	57.32	571.32	-
Domestic	734.0					
Estimates	222.0					

offshoot of a Lake Conservation and Beautification Project of the Urban Developmental Engineering Department. It is expected to extract up to 3 tons/day of weed from Dal Lake. If gassified and supplied to adjacent hotels for cooking purposes, a savings of about 35,000 liters of kerosene is expected.

Geothermal energy. The Geological Survey of India has identified the hot springs of Puga Valley (Ladakh) as a potential source of geothermal energy. Boring to a level of 224.30 meters has

Table 11: Five Year Plan 1985-90 and Annual Plan 1985 - 86—Jammu and Kashmir State

Rs. In Lakhs

Name of the Scheme	Allocation Centre 1984-85	Actual Expenditure 1984-85	7th Plan 1985 - 90 Outlay State	7th Plan 1985 - 90 Outlay Centre Expected	Annual Plan 1985 - 86 Outlay State	Annual Plan 1985 - 86 Outlay Centre Expected
1. Solar Electrification	Nil	0.023	15.0	100.00	3.00	13.00
2. Solar Cookers	6.00	-	2.50	5.00	0.50	1.00
3. Solar Air Heating	1.5	Nil	2.50	10.00	0.50	1.50
4. Solar Water Heating	6.50	Nil	2.50	10.00	0.50	1.00
5. Solar Timber Kiln	1.00	Nil	5.00	5.00	1.00	1.00
6. Solar Driers	0.50	Nil	2.50	5.00	0.50	1.00
7. Solar Architecture	Nil	Nil	5.00	10.00	1.00	1.00
8. Solar Stills	Nil	Nil	3.75	5.00	0.75	1.00
9. Wind Pumps	Nil	Nil	2.50	5.00	0.50	Nil
10. Aero-generators	Nil	Nil	15.00	100.00	3.00	10.00
11. Bio-gas (Community/Inst.)	Nil	Nil	100.00	2.00		
12. Sewage Gas	Nil	Nil	5.00	100.00	1.00	10.00
13. Weed Gasifications	Nil	Nil	10.00	40.00	2.00	8.00
14. Wood Gasifications	Nil	Nil	17.50	50.00	3.50	5.00
15. Briquetting/Pelletisation	Nil	Nil	7.50	15.00	1.50	3.00
16. Energy Plantation	Nil	Nil	0.50	2.50	0.10	0.50

Source: The New and Renewable Energy Thrust of the J & K Govt. A Factual Report by Arun Kumar, IAS Additional Secretary, Govt. of J & K, Power Development Department, Srinagar.

been done and a temperature of 123.4°C has been obtained. In the current year the ONGC hopes to drill up to 500 meters and is likely to hit a temperature of 200°C.

Alternate sources of energy in the coming years will play a vital role in the socioeconomic tranformation of the state, but success will depend largely on the extent to which solutions to various technical, economic, social, and organizational problems can be found (Dayal 1984).

CONCLUSIONS

It should be clear from the information presented in this paper that, barring hydel and fuelwood, Jammu and Kashmir lack natural resources, such as coal, petroleum, gas, and geothermal, for power generation. They have not been able to utilize adequately their full hydel power potential. The slackness in hydel development has been largely because, in the early phase of planning for power development, energy planners stressed the development and completion of the major hydel projects such as Salal and Uri. These have not materialized. Consequently, Jammu and Kashmir are plagued by a chronic power shortage, so that during winter, when hydel power generation is significantly reduced due to adverse climatic conditions, electricity in the entire region and particularly in the Valley is strictly rationed and is not available for more than 8 hours in a 24-hour period.

Inordinate delays in the execution of major hydel projects and the consequent acute scarcity of power has forced state energy planners to shift their emphasis to the development of micro and mini hydel plants. They have now identified the development of 726 MW, 301 MW, and 54 MW minor and micro hydel power in the Valley, Jammu, and Leh Kargil regions. Of this, they have been able to develop and utilize only 93 MW in the Valley and 60 MW in Jammu. In addition, nearly 60 MW are obtained through the northern grid. These are being raised to 75 MW through the use of capacitors. This is totally insufficient to meet the peak demand, which far exceeds the supply of 956 million units in 1984-85. Furthermore, the supply is drastically curtailed during the winter season.

Rural-urban competition for power supply is equally acute. Both in the Valley and the Jammu regions, the capital cities of Srinagar and Jammu are the largest consumers of power and their capacity to consume power is insatiable. At the moment, these two cities together account for about 50 percent of the total power units sold in the state. Their industrial development has been retarded for want of power. If power is made available, industrial, commercial, and domestic consumption of power will increase by geometrical proportions in these two cities. This will retard rural electrification and use of power for agriculture.

Another disturbing ecological problem in the development of power is the desire to preserve mountain ecology which militates against the compelling need to use firewood as a source of fuel both in urban and rural areas. In urban areas, firewood is a rationed commodity. The annual approximate consumption of 26 million quintals of firewood in the state has led to massive deforestation; consequent soil erosion has adversely affected mountain ecology. It has been estimated by the Advisory Board on Energy in India that this state would need by 2004/05 A.D. 3 million tons of fuelwood: 2.4 and 0.6 million tons respectively for rural and urban areas. In order to prevent this phenomenon from assuming catastrophic proportions, the state needs accelerated programs of: energy plantation; extension of electricity network to rural areas for domestic consumption with assured supply of power; and diversification of power resources in the state by tapping nonconventional sources of power; and establishment of thermal power stations.

1. The state has a World Bank-aided social forestry program which has so far covered the 86,000 and 332,000 hectares of wasteland in the Valley and the Jammu regions respectively. Technology is now available to use fuelwood for power generation. For instance, bagasse is being used for the generation of power in sugar factories. In Gujarat, an experimental fuelwood-based pilot power generating station has been set up.

2. A direct relationship between the rise in per capita income and power consumption has been established by numerous studies. In a recent study on fuelwood consumption in Hyderabad, income-power consumption elasticity has been well demonstrated (Alam et al 1985). The per capita income in the state has been rising both in the urban and rural sectors. It is therefore obvious that power consumption will also rise in proportion to the growth of income. Hence, in order to meet rising energy demands of the various sectors in the state, hydel power generation has to be accelerated.

3. There is little development of nonconventional sources of energy; although some schemes were drawn up during the Sixth Plan Period, none were implemented. In the Seventh Plan, these schemes have been transferred to the State Department of Power for implementation. The inadequacy of development of nonconventional sources of energy is highlighted in Table 11.

4. In order to overcome the acute and chronic scarcity of power in thestate, the establishment of a major thermal power station is a vital necessity to ensure rapid and sustained economic development. This was also recommended by a national seminar on energy in Jammu and Kashmir.

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ENERGY-USE PATTERNS AND ENVIRONMENTAL CONSERVATION: THE CENTRAL HIMALAYAN CASE

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INTRODUCTION

A large part of the world today, the so-called Third World, depends primarily on biomass (food and wood), or "low-energy" sources, as opposed to "high-energy" sources, or fossil fuel, relied upon in the developed world (Odum 1983). This conspicuous difference in energy sources corresponds to the difference in per capita income between low-energy and high-energy parts of the world. The entire Himalaya, including the central part, comes under the low-energy category. Contrary to expectations held at the first International Conference for Peaceful Uses of Atomic Energy, Geneva, in 1955,[1] that the atomic age would close the gap between rich and poor leading to a state of equal and abundant energy for all, the dream cannot materialize because of the enormous "disorder potential" derived from using atomic energy (Wilson 1979).

Thus, at this juncture when fossil fuels are being depleted and the use of atomic energy continues to be a dream, the human mind is faced with the problem of developing alternative energy sources. In the Himalaya, people are still at the subsistence economy level and are faced with problems of dwindling biomass energy sources.

The heterogeneity (of climate, vegetation, culture, etc.) in the Himalaya calls for developing various models. The mountain ranges of the Central Himalaya have been particularly prone to landslides due to seismicity and tectonic stress (Valdiya 1985). Compared to the eastern region, it is drier, but more humid than the western region. The contribution of winter rains to the annual rainfall in the central region is remarkably less than in the west. The differences in climatic factors and those in geological history have caused differences in progress of vegetation and, concomitantly, in progress of human civilization of these three principal regions of the Himalaya. Through a number of perennial and annual rivers, the Central Himalayan mountains have profoundly shaped the development of the adjacent plains, also called the shadow zone of the mountain chains. The densely populated shadow zone, subject to extensive and intensive agricultural activities and varying stages of industrialization, have in turn influenced these central mountains.

In this paper, energy-use patterns and natural resource conservation are analyzed through an ecosystem approach that includes an attempt to link ecosystems of the mountain region with those of the shadow plains and vice-versa. The basic tenet is that in the large ecosystem of both the mountains and plains, the role of the former is mainly protective. Consequently, our search for energy sources focuses on low-energy sources (biomass plus nonconventional sources of energy) required to rejuvenate the subsistence economy in the mountains.

ENVIRONMENTAL BACKGROUND

Located between 28° 30' and 31°30' latitude and 77° and 81° longitude, the Indian Central Himalaya (Uttar Pradesh Himalaya) covers an area of about 51,000 km^2. In the north, it borders Tibet while toward the east, the river Kali marks its border with Nepal (Fig. 1). Toward the west lies Himachal Pradesh, and in the southwest and south, the region touches the boundary of plains districts, the westernmost being Saharanpur and the easternmost being Pilibhit.

Along the southern edge, the mountains rise abruptly from the alluvial plains. The Siwaliks, the first and southernmost mountains (10 to 50 km wide) stand 500 to 1200 meters high. They are separated from the Lesser Himalaya (also called outer or middle Himalaya) to the north by a major fault, the Main Boundary Thrust (MBT). The lesser Himalaya, where northwest-to-southwest ranges rise sharply to 2500 meters and above, is characterized by the presence of numerous transverse valleys. The river gorges provide only occasional, difficult access routes to the inner mountains. Beyond the outer ranges lie the Greater Himalayan ranges which are separated from the former on the south by the Main Central Thrust (MCT). In the ranges of the Greater Himalaya lie another series of valleys, then finally their headwaters in the glaciers and permanent snows. Most land is above 5000 meters, and many of the world's highest peaks rising above 7000 meters are in this region.

Between the deep alluvial plains and the Siwaliks, thin belts of *bhabar* toward the mountains and of *terai* toward the plains are identifiable. The *bhabar* is a 15 to 25 km wide belt of talus gravel slopes deposited by the Himalayan rivers. For much of the year, the mountain streams subside beneath the *bhabar*, emerging again slowly to carry finer alluvial silts into the *terai*, he level belt of super abundant surfacewater (10 to 25 km wide). Contiguous to the *bhabar* but structurally between the Siwaliks and the Lesser Himalaya, another landform called *duns* can be recognized. Dehradun, a major city of the region, is the most well-known example of a *dun*.

As in the rest of the subcontinent, the rainfall pattern is largely governed by the monsoon. Its influence increases with elevation up to about 2200 meters, and then declines with further rise (Table 1). In general, the monsoon (mid-June to mid-September) accounts for 60 to 80 percent of the annual rainfall. The contribution of winter rainfall (8 to 29 pecent) occurring due to western disturbances (Dhar et al 1984) tends to increase from east to west. The monsoon rainfall is of the order of 1000 mm in the foothills, 2000 mm in the middle elevations, and 500 mm in higher elevations and interior regions (Dhar et al 1984).

The monsoon period, which is also warm, is the most favorable for plant growth, and most ecosystem activities appear to be directly or indirectly

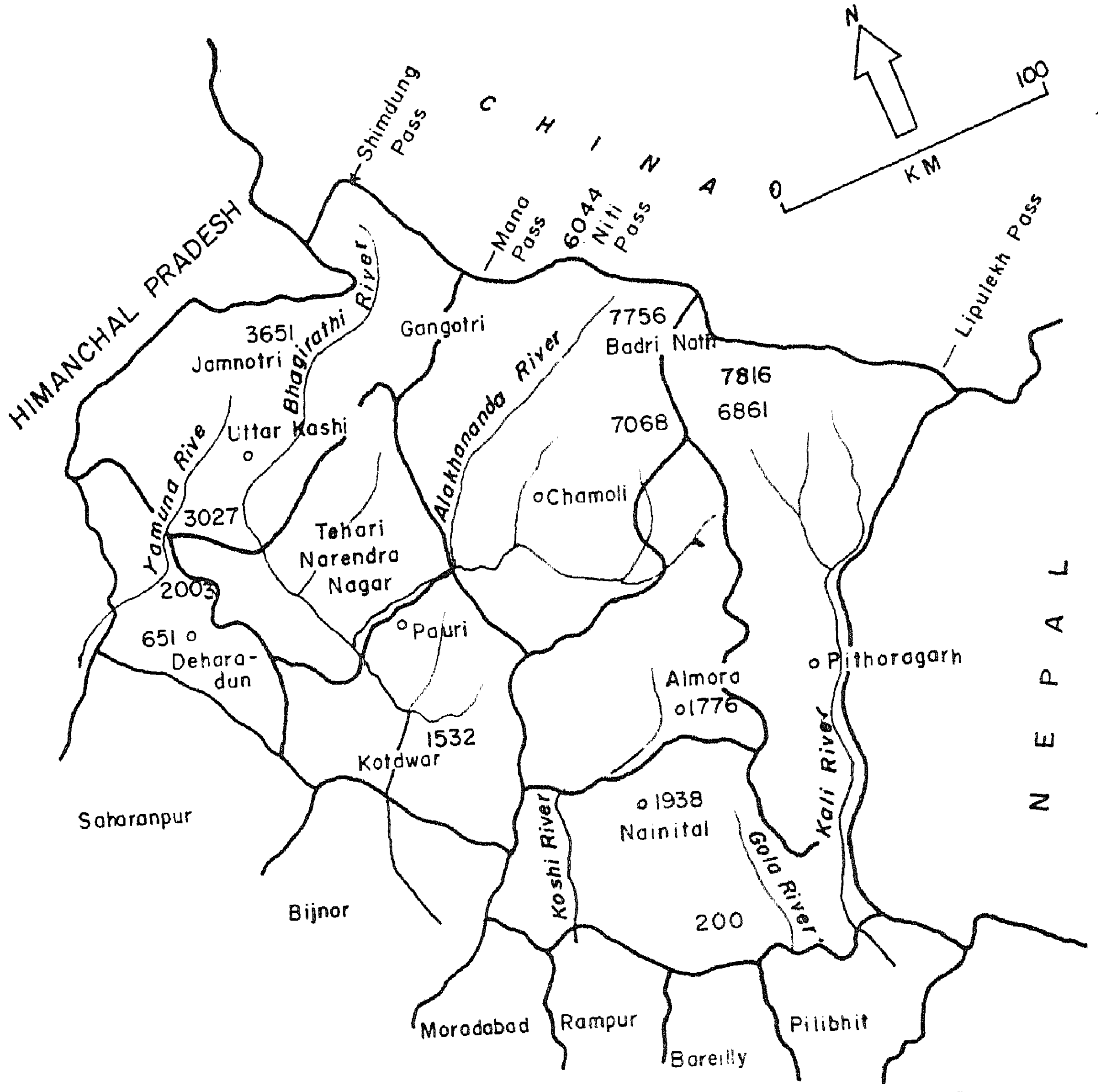

FIGURE I. INDIAN CENTRAL HIMALAYA AND ADJACENT PLAINS.

Table 1: Rainfall (mm) Conditions in Different Landforms of the Central Himalaya (Values are average of 6 years)

Locations	No. of Stations	Seasons			Total
		Winter (Nov - Feb)	Summer (March - June)	Rainy (July - Oct.)	
Terai	4	124.0	220.3	1096.3	1440.6
Bhabar	4	121.1	360.3	1403.4	1884.8
Frontal ranges of Siwalik and adjoining Lesser Himalaya	4	125.4	435.0	1855.6	2416.0
Interior Locations in Lesser Himalaya	13	119.5	349.5	894.4	1367.4
Rainshadow area	1	-	201.0	519.0	720.0

related to this period (Singh and Singh 1985a).

A rise of 1000 meters corresponds to a fall of 3.7°C in mean annual temperature. In the elevational belt of 1500 to 2000 meters, the mean monthly temperature ranges between 5.5°C and 8°C in the coldest month of January and between 19°C and 27°C in the hottest month of June. The above values in the *bhabar* zone range from 13 to 21°C in the coldest month and between 30 and 40°C in the hottest month. Snowfall during the winter season is frequent above 2000 meters.

Singh and Singh (1985a,b) have reviewed the structural and functional aspects of forest vegetation mostly on the basis of quantitative studies made earlier (e.g. Chaturvedi and Singh 1982; Pandey et al 1983; Negi et al 1983; Pandey and Singh 1981a, 1981b, 1982b, 1982, 1984a, 1984b, 1984c; Ralhan et al 1985a, 1985b; Pathak et al 1984; Saxena and Singh 1982a, 1982b; Saxena et al 1983; Singh et al 1984; Tewari and Singh 1981; Tewari and Singh 1983; Tewari et al 1984; Upreti et al 1985). In general, from lower to higher elevations the following forests prevail: *Sal* (*Shorea robusta*) forest below 1000 meters; *chir* pine (*Pinus roxburghii*) forest between 100 and 1700 meters; *banj eak* (*Quercus leucotrichophora*) forest between 1500 and 2200 meters; and *kharsu oak* (*O.semecarpifelia*), conifer forest (*Pinus Wallichiana*), and *Abies pindrow* (*Cedrus deodara*) above 2200 meters.

The Himalayan catchments are subsurface flow systems, and therefore are particularly prone to landslides, which become a serious problem in areas without tree cover. However, since the climate is benign in the middle elevation belt, the recovery of forests such as oak forests is rapid, provided biotic stress does not persist. In forests subject to low biotic stress, biomass value as high as above 700 dry matter per hectare is recorded, particularly in oak and *sal* forests. This value approaches the higher side of the forest biomass range reported for the world. The net primary productivity ranges between 11.0 to 27.4 tons per hectare per year. The higher values are comparable with those of highly productive forests of the world (Lieth 1973; Whittaker 1975). Compared to the world's temperate forests, larger amounts of nutrients accumulate in the biomass pool of these forests. Therefore, removal of forests means greater depletion of nutrients from temperate forest ecosystems.

According to the 1981 census, the population of eight districts of the Indian Central Himalaya was about 5.10 million, of which 3.47 million was in the mountains. Of the mountain population, nearly 82 percent was rural, with a density of about 77 per km^2 for the entire area, 72 for the rural sector, and 776 for the urban sector. The rate of population growth was 2.3 percent per year. Subsistence agriculture involving forest resources has been the occupation of most of the population for the last several centuries. According to Khanka (1985) the net migration (emigration minus immigration), for example, in Almora District was 13.5 percent and 9.4 percent of the population respectively in 1961 and 1971. Interestingly, emigration is directly related to literacy level, which is higher than in Uttar Pradesh (38 percent in Kumaun region as opposed to 27.4 percent in Uttar Pradesh in 1981) and size of land holdings. Although emigration increases the percentage of children, old people, and women, it is economically beneficial, as the earnings are higher at destination than at origin (Khanka 1985). However, the level of the mountain economy remains at the subsistence level.

THE PROBLEMS

Thompson and Warburton (1985) point out that the Himalaya have a plurality of contradictory and contending problems--each one focused by the shared credibility it enjoys in the eyes of those who subscribe to it. Such confusion is likely to arise when data is generalized across the entire Himalaya region and when the investigators do not belong to the region. The authors feel that the Indian Central Himalaya is relatively homogenous in landscape, population structure, and cultural attributes. The single major problem is how to revive the forest cover which, according to one estimate (Shah 1982), is on the verge of extinction.

This point is elaborated in the following statements:

1. Historically, subsistence agriculture and unregulated and illegal commercial exploitation of forests (Misra and Tripathi 1978) have led to the present state of inadequate forest cover.

2. Forest biomass provides an ecosystem structure which moderates oscillation in climate, checks total discharge of water, storm flows, and flood peaks in catchment (Hibbert 1967; Gilmour 1977) and reduces the frequency of landslides (Haigh 1984).

3. Deforestation led to the extinction of springs, the precious water source for domestic use (K.S. Valdiya).[2]

4. Deforestation not only impairs the life-support system of the soil, it also exposes the land to the destabilizing physical forces of rain, wind, and solar energy.

5. Such an impairment in hydrological cycle has caused recurrent flooding of plains.

6. These processes have combined to impair not only the infrastructure, which sustains the subsistence economy in the mountains, but has also has caused environmental degradation in the plains.

Any development plan which seeks to improve the energy-use pattern in the region needs to keep the above facts in view. The impaired energy-use pattern ought to be revived before attempts to provide new energy subsidies to the people are made.

COMPARTMENTALIZATION OF LANDSCAPE IN VIEW OF PRINCIPLES OF ECOSYSTEM DEVELOPMENT

According to the principles of ecosystem development in relation to the landscape as a whole, Odum (1983) recognized three types of life-supporting systems and an urban-industrial, heterotrophic system as the fourth type. The life supporting-systems include:

1. The human productive system or growth system(e.g. croplands, tree plantations, and intensively managed forests that provide food, wood, manure, and fibre)

2. Manure systems--the protective life support system which is more protective than productive, stabilizes and buffers the air and water cycle, and moderates temperature and other physical factors, while at the same time providing materials for human use (e.g. old-growth forests and climax grasslands).

3. Waste assimilative system, which is natural or semi-natural and that bears the brunt of assimilating the wastes produced by the urban-industrial and agricultural system (i.e. waterways, wetlands, and other environments receiving strong impacts)

Looking at the compartmentalization of the Indian Central Himalaya (including the plains of Nainital and Dehradun Districts) today, about 15 percent of the total area is in agro-ecosystem (cropland, current fallow, rural house, etc.) and less than 2 percent is in urban-industrial system (including rural roads), leaving about 83 percent as so-called natural systems, variously affected by firewood and timber harvesting, lopping, grazing, recreation, and pollution (Tables 2 and 3). However, a sizeable portion (about one-fourth of the total area) of the natural area is either devoid of vegetal cover or has negligible vegetal cover (rocks and severely eroded land, Table 2) and cannot be assigned to any category given by Odum. This is natural,

Table 2: Land-Use and Forest Cover in the Indian Central Himalaya

Land-Use	Area (km^2)	Percent of total area
Non-Forest[a]		
Snow [a1]	11003	21.59
High-Altitude Meadows[a1]	2522	4.95
Agriculture[b]	6975	13.69
Urban[b]	.575	1.13
Urban construction[b] (including roads, canals, etc)	1050	2.05
Rocks and Severely Eroded Land (almost devoid of vegetation[b])	2461	4.83
Low-and Mid-altitude Grasslands[b1]	354	0.69
Degraded Vegetation [c]	11374	22.32
Total Non-Forest	36314	71.27
Forest[a]		
Poor Forest	4709	9.24
Medium Forest	7666	15.05
Good Forest	2263	4.44
Total Forest	14638	28.73
Total Reported Area	50952	100.00

[a] After Singh et al (1984 a), interpreted from satellite imageries

[a1] The aread mostly covered by snow and high-altitude meadows for which imageries are not available was partitioned into snow and high-altitude meadows by using the proportions of snow and high-altitude meadows in other high-altitude areas for which imageries were availabel (Singh et al 1984a, b). The respective values were added to the known values to calculate total area under snow and high-altitude meadows.

[b] Derived from Anonymous (1982); urban areas do not include those of plains of Nainital and Dehradun.

[b1] Estimated by deducting the area reported for high-altitude meadows by Singh et al (1984a) from the sum of area reported for high-altitude pastures and other pastures in Anonymous (1982).

[c] Estimated by deducting the sum of areas reported for other non-forest landuses in the table (after Anonymous 1982) from the total area reported for non-forest by Singh et al (1984 a). This degraded vegetation category includes all the degraded forms converted, presumably from the original forests, e.g., scrubs, grasslands, weeds (such as lantana camara) - dominated vegetation, with a few scattered denuded trees.

Table 3: Compartmentalization of the Central Himalayan Landscape According to the Ecosystem Development Theory (percentage area assigned to various categories are approximations derived from Table 2)

System Category	Examples	Percentage of total area
Protective system	Forests	28.7
Productive system	Croplands, including current and old fallows and village settlements	15.7
Degraded systems	Mostly the land originally under forests, but now "blanks" subject to various destabilizing forests, plus water bodies	22.3
Non-biological systems	Permanent snow and rocks, almost completely devoid of vegetation	26.4
Urban-industrial	Mostly urban settlements, also includes roads	1.9
Unidentified		5.0

but almost a non-biological system. Like the urban-industrial system, solar radiation impinges upon these systems without being utilized in biological terms. But unlike the urban-industrial system, it is mostly devoid of human activity. Another large category (accounting for about 22 percent of the total area) is of severely impacted natural systems, termed "degraded systems". Both biomass and productivity of the various ecosystems of this category (grasslands, scrubs, weed-dominated ecosystem, etc.) represent a small fraction of the potential values. The vegetal cover is seasonal and often less than 25 percent of ground surface (Singh and Saxena 1980). Far from assuming the protective role, these ecosystems themselves are subject to destabilizing forces, thus losing huge amounts of soil, nutrients, and organic matter. Although, in view of the fact that such systems represent arrested successional stages, they can be recognized as the dissipation category of Odum. Their structural parameters are so reduced that they can hardly assimilate wastes derived from other systems. Unfortunately, the poor forest category given in Table 2, with the crown density of 10 to 30 percent, is on the verge of being converted to degraded ecosystem.

Compared to a highly industrialized

country like the U.S.A. (Odum 1983) where about 70 percent is healthy natural environment consisting mostly of forests and climax grasslands which support 24 percent in domesticated environments (agro-ecosystems) and 6 percent in urban-industrial areas (fabricated environments), the situation is gloomy in the Central Himalaya.

This area, characterized by negligible use of fossil fuel, low population density, and continued conversion of protective systems into destabilized ones, is surrounded by the vast, densely populated plains, which interact with the mountains variously where domesticated and fabricated systems are predominant. Thus, the impending situation is that of a mountainous region with a sizeable proportion of non-biological systems and a large proportion of degraded natural systems interacting with a plains region with large area in agro-industrial complexes. The destabilizing potential of such interaction could be profound.

ENERGY IN VARIOUS ECOSYSTEMS

Forests, grasslands, and croplands are the main ecosystems in the Central Himalaya. Of these, forests are by far the most important potential ecosystems in the mid-montane belt or agricultural zone. In this zone, grasslands in patches have developed owing to deforestation, heavy grazing, and fires (Singh and Saxena 1980). About 14 percent of the total land is under crops. The net primary productivity in terms of energy for various ecosystems is given in Tables 4, 5, 6, 7 and 8. It is apparent that, in general, forests are far more productive than the grasslands and croplands. In fact, most of the production values for forest ecosystems are in the range of the lower values reported for highly productive communities of the world (Singh and Singh 1984). Singh and Singh (1985a) pointed out that climatic conditions are favorable for forest growth. By and large, net primary productivity of our converted grasslands is markedly lower than those in the north temperate zone, where grasslands usually represent the climax stage (Ryszkowski 1985). It appears that the converted grasslands of the Central Himalaya are subject to destabilizing forces, such as excessive grazing and frequent burning, which lead to soil and nutrient loss under the influence of rainfall and wind. The destabilizing effect of the rainfall is likely to be particularly severe in this region, where most of the rainfall is confined to a short monsoon period, soil depths are shallow, and rocks are immature. With the conversion of natural ecosystem (in this case, forests) to grassland, or agricultural ecosystem, initially the availability of nutrients is increased above availability in the natural ecosystem prior to disturbance, but subsequently the impairment of biotic control leads to lower nutrient pool size than in natural ecosystems (Melillo 1985). Apart from the adverse effect of these destabilizing forces, lower productivity in grasslands and agricultural ecosystems is because of shorter growth periods.

Lack of irrigation water, fertilizer, and other productive inputs also limits agricultural productivity. Several indirect observations indicate the severity of degradation over large areas (Chand and Thakur 1985). Cox (1985) pointed out that although the use of

Table 4: Net Above ground Production of the Central Himalayan Forests along an Elevational Gradient of 300-2200 m (based on Rana and Singh 1984)

Forest	Altitude (m)	Net Above ground Production ($\times 10^6$ kcal/ha/yr)
Sal old growth forest	300	65.1
Sal seedling coppice forest	330	74.3
Pine-mixed broad-leaf forest	1350	41.5
Pine forest	1750	66.1
Mixed oak pine forest	1850	67.0
Rianj-dominated mixed oak forest	2150	76.7
Tilong-dominated mixed oak forest	2200	103.2

inputs is able to raise the net primary productivity levels of the agro-ecosystem of a region, this success is presumably realized only on agricultural land that has not been severely degraded.

The above comparison is based on total net primary productivity. However, in an agricultural ecosystem, the aim is to maximize the agronomic yield--usually grains and tubers. In forest ecosystems, wood (trunk and major branches) is of greater significance, for it is the material of commerce. From this standpoint also, forests are far more productive than croplands.

Energy Linkages Between Agro and Forest Ecosystems

In this region, cultivated land is the "nucleus" of human settlements. Because of the dynamic interdependence between cultivated and the adjacent uncultivated lands, it would be useful to examine energy flow relations to understand the Central Himalayan situation. An energy-flow diagram given in Fig. 2* roughly represents the average situation, though several values are based on inadequate samples, the number and size of which also vary from one parameter to another. However, all such samples are from the agricultural zone, also called the mid-mountains (1000 to 2200 meters), which is the zone of major environmental problems. The model of energy flow is that designed by Pandey and Singh (1984c). In this representation, quantities of all possible inputs (human and animal labor, manure, chemical fertilizers, seeds, etc.) outputs (yield of edible crop products, crop byproducts, and milk), sources and supply of animal fodder, and the human use of firewood have been considered. The input and output

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* The average energy flow through the human use system for the Central Himalayan rural areas. All values are in 10^5 kcal/yr/ha of cultivation for method of computation, see Appendix 1.

Table 5: **Net Above ground Production (x 10^6 Kcal/ha/yr) of herbaceous vegetation in Central Himalaya**

Site	Author	Net Annual Above ground Production		
		Live	Currend dead	Total
Kumaon Himalaya (between 1000-2000 m)	Saxena and Singh (1980[a])			
Open grassland		16.96 - 26.22	3.85 - 6.09	20.81 - 32.27
Chir pine forest		1.08 - 4.16	0.16 - 0.83	1.29 - 4.99
Mixed forest		0.92 - 2.52	0	0.92 - 2.52
Banj oak forest		0.39 - 1.74	0.03 - 0.67	0.42 - 2.40
Tilong oak forest		0.13 - 0.91	0.01 - 0.56	0.14 - 1.47
Kumaon Himalaya	Khanna, R.K. and S.P. Singh. (unpubl[b].)			
Grassland around cultivated land				
- protected		34.34		
- un-protected		15.85		
Kumaon Himalaya (between 1000-1800 m)	Singh (1984[c])			
Chir pine forest with relatively closer canopy		4.83		
Chir pine forest, open canopy with few seed bearers		10.37		
Chir pine forest, open canopy with no adult tree		12.91		
Open grassland near streams	18.36			
Grass mixed with lantana camara	10.55			
Adjustment with cropland		22.01		
Single species grasslands on terrace faces	Gupta (1967[a])			
Bhatta, Mussorie average of seven stands				37.53
Gopeshwar	V. K. Shah (Pers. Communication)			43.22
Garhwal Himalaya (1500 m)				
Alpine grasslands	Jeet Ram (Pers. Communication)			14.71

a Production in terms of peak biomass, sites relatively undisturbed

b Production computed on the basis of time-interval harvests

c Only grasses considered (production in term peak-biomass)

Table 6: Net Aboveground Production (agronomic yield plus byproducts) in croplands of the Central Himalaya)

Village	Production (X 10^6 kcal/ha/yr)	Author
Khurpatal	47.13	Panday & Singh (1984)
Balutia	17.25	
Mehragoon	5.81	
Siloti	20.34	
Chanoti	18.71	
Average	21.85	

Table 7: Rate of exploitation of various resources from the entire Central Himalayan forested area (14.64 x 10^5 ha)

Resources/Causes of exploitation	Quantity
Total aboveground production	82.00
Firewood[a]	14.90
Timber	1.47
Fodder[b]	16.43
Losses associated with harvests[c]	1.12
Minor products[d]	2.77
Forest clearance	
- due to agricultural expansion[e]	12.40
- due to the constructional works	?
Burning and natural catastrophe	?
Total known exploitation	49.09

[a] At the rate of 2.5 kg per capita per day, which has found reasonable for the entire geographical area by Nautiyal andBarbor (1985)

[b] Only the amount harvested from forests considered, and it includes requirements of goat and sheep.

[c] Leaves and minor shoots unused but destroyed due to the harvest of major woody parts.

[d] Resin, medicinal plants, bamboos etc.

[e] Rate of forest clearance is 0.9% of the area for the period, 1958-1973 (Shah, 1982). Data which were not referred to above derived from (Anonymous 1983)

Table 8. Partitioning of average Aboveground Net Production (x 10^6 Kcal ha -1 yr -1) across seven representative forest types (e.g., sal, pine, oak, and mixed forests) between 300-2200 m elevation of Kumaon Himalaya (computed from Rana and Singh, 1984)

Aboveground components	Average	Range
Tree: Woody components		
Trunk	22.89	9.8-36.5
Branches	8.70	3.4-19.7
Twigs	12.06	5.6-20.4
Shrub: Woody components	1.44	0.3- 2.3
Total Woody components	45.09	21.3-77.3
Tree leaves	19.97	13.2-25.8
Shrub Leaves	1.53	0.2- 3.3
Herbaceous aboveground	3.50	2.2- 4.9
Total non-woody	25.00	0.2-25.8
Total aboveground	70.09	0.2-77.3

quantities were converted to energy values, multiplying by appropriate caloric equivalents given in Mitchel (1979), who developed them using mainly the values given in Pimentel et al (1973) and Gopalan et al (1976). All the values are represented per hectare of cultivated land, which exclude the plains of Nainital and Dehradun Districts. Details of the method followed for computing various values are given in Appendix 1.

It is apparent from Fig. 2 that the agronomic yield (plus milk) 47.5 x 10^6 kcal per hectare of cultivation is adequate for only half a year's food requirement of the mountain population; the remaining half is imported from the plains.

The urban population per hectare of cultivation is nearly 0.6, compared to 7.0 for the rural population. However, the pressure of population can be in the

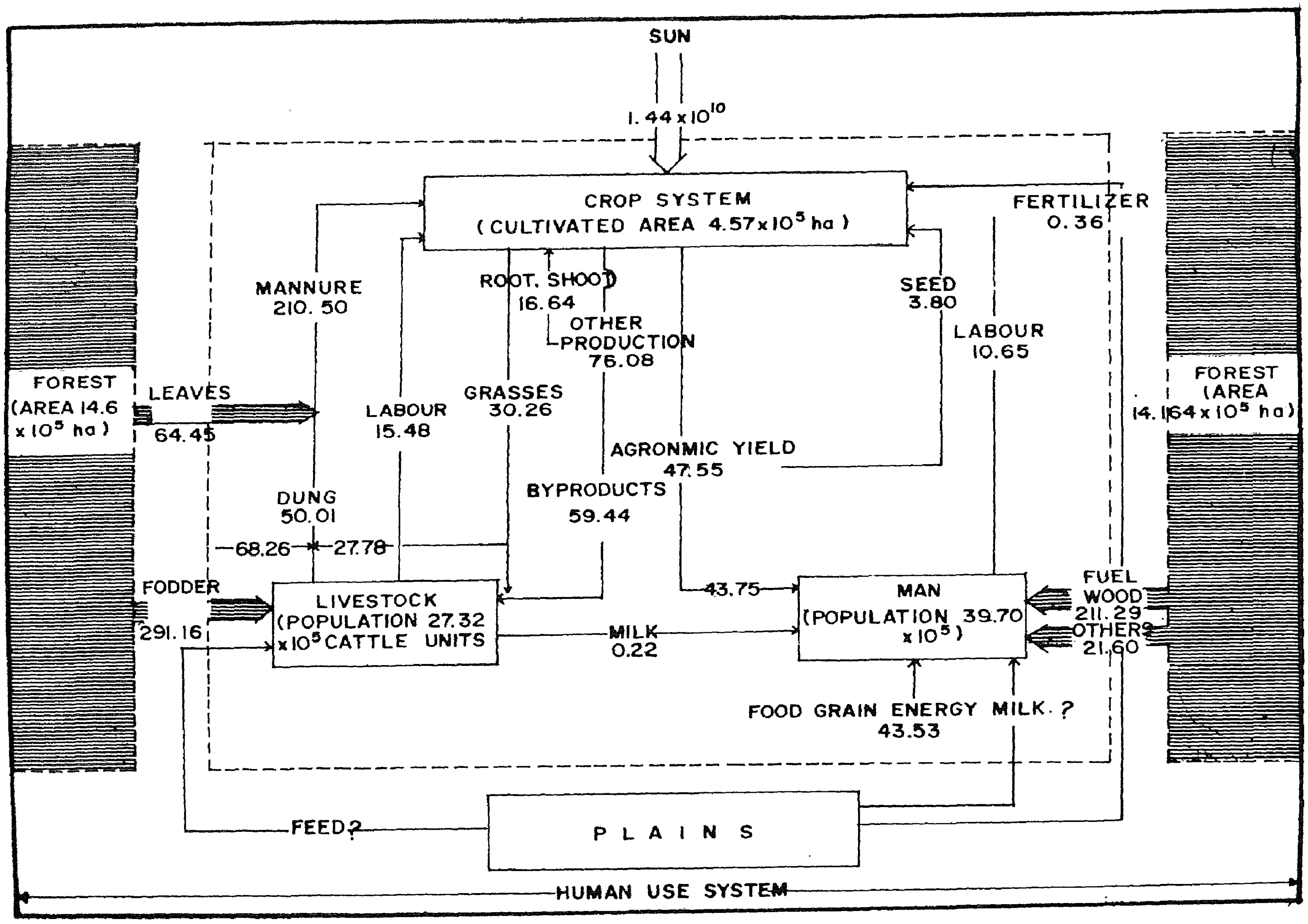
SUN
1.44 x 10^10
CROP SYSTEM (CULTIVATED AREA 4.57x10^5 ha)
FERTILIZER 0.36
MANNURE 210.50
ROOT, SHOOT 16.64
OTHER PRODUCTION 76.08
SEED 3.80
LABOUR 10.65
FOREST (AREA 14.6 x 10^5 ha)
LEAVES 64.45
LABOUR 15.48
GRASSES 30.26
AGRONMIC YIELD 47.55
FOREST (AREA 14.164 x 10^5 ha)
DUNG 50.01
BYPRODUCTS 59.44
68.26
27.78
FODDER 291.16
LIVESTOCK (POPULATION 27.32 x10^5 CATTLE UNITS
43.75
MAN (POPULATION 39.70 x 10^5)
FUEL WOOD 211.29
OTHERS 21.60
MILK 0.22
FOOD GRAIN ENERGY MILK ?
43.53
FEED?
PLAINS
HUMAN USE SYSTEM

Figure 2

range of 12 to 17 per hectare of cultivated land in certain parts of the mid-mountain belt, where the import of food grain can be up to 75 percent of the requirement (Ashish 1983).

In total, for each unit of energy employed in agronomic (plus milk) production, about 12 units[3] of energy are expended from the forest ecosystem mainly in the form of fodder and fuelwood requirements. Here, the forest also includes those forests which have been recently converted into degraded land with grass and scrubs. This is higher than the average values of seven units reported by Pandey and Singh (1984c) and Singh et al (1984a) for three villages of the mid-mountain belt of Kumaon Himalaya. However, Pandey and Singh (1984c) admitted that the value of energy from the forest was likely to be higher, if the amount of tree leaves collected for manuring was included.

An ecosystem is stable as long as its net ecosystem production (NEP) is not negative (Melillo 1985). The sum of manure input and the amount of unharvested crop is about twice as much as the total harvest. However, in order to calculate NEP, heterotrophic respiration and losses of organic matter as a consequence of erosion also need to be accounted for. According to the estimate of Shah (1982), nearly 85 percent of cultivated land is suffering from severe erosion problems.

Further, the stability of the support system of cultivation, i.e. the forest system, is being increasingly threatened. The total forested area of 14.64 x 10^5 hectares contains 1363 x 10^{12} kcal in above-ground live biomass and maintains a net annual production of about 82 x 10^{12} kcal. Approximate information of forest exploitation including fuelwood, timber, fodder, minor production, and clearance of forests due to the expansion of agriculture are given in Table 7. However, it is not known how much forest is destroyed annually for construction work, burning, natural or man-made landslides, deposition of debris, etc. The known forest harvests (49.09 x 10^{12} kcal) amount to about 60 percent of above-ground annual production. According to Shah (1982) about 6.8 percent of forest growing stock is exploited annually, which converts to 93.6 x 10^{12} kcal per year. which is 14 percent greater than net above-ground production. Using this rate of forest exploitation, Singh et al (1985) concluded that the Central Himalayan forests show a net release of 4.6 x 10^{12} gega calories (g. c.) per year. Whether or not the annual forest harvest is greater than the annual production, it is beyond doubt that the harvest far exceeds carrying capacity and forest stock is diminishing with time (Singh and Singh 1984). The processes associated with even 60 percent harvest of above- ground annual production would involve corresponding losses of nutrients and organic matter and the adverse effects of trampling, browsing, grazing, lopping, erosion, etc., on the regeneration of forests. Biomass quantities cannot measure the potential adverse effects of loss of a seedling on forest regeneration. The perpetual biotic stress, even at a small scale, impedes recovery, which in its absence would have occured at the expense of rapid release of energy stored in forest litter mass (22 x 10^{12} kcal in entire forested area) and soil (530 x 10^{12} kcal in entire forested area). Thus, the unregulated biotic stress is not only removing the biomass directly, it is also resulting in the loss of structural component of soil, and the energy capital which would have supported the initial ecosystem development (Bormann and Likens 1979).

Apart from the above, unregulated exploitation leads to large-scale changes in forest composition involving conversion of old-growth to second-growth forests, dominated by a few light-demanding species and to concomitant reduction in diversity and population of fodder species (Saxena et al 1985).

Further, the intensity of exploitation of forest resources would be maximum in easily approachable areas. Airy and Shastri (1984) observed that the denudation of forest is directly related to development. We assume that the forests exploited by villagers belong to the poor category (with crown cover of 10 to 30 percent). Distributed over 4.71 x 10^5 hectare, these forests are reported to attain an average ANP of about 34 x 10^6 kcal per hectare per year. Thus the energy available in terms of ANP per hectare of cultivated land is about 35 x 10^6 kcal per year from this category of forest, compared tothe annual village requirement of about 59 x 10^6 kcal per hectare of cultivation. Consequently, denuded areas around cultivated land are widening over time.

A WORKABLE MODEL FOR ECOLOGICALLY SUSTAINABLE DEVELOPMENT IN VIEW OF SOCIOPOLITICAL CONSTRAINTS

Theory alone is not sufficient to discover an integrated model of development that is both ecologically sustainable and sociopolitically feasible. Results of practical experiences need to be added to theoretical parameters. Any development model for the Central Himalaya needs to consider that the region is inseparable from the adjacent plains. Keeping in view ecological sustainability, we assign a protective role to mountain ecosystems. Protective systems in mountains will check the flood-peaks and downhill movement of soil, silt, and stones; the productive systems of plains will take care of the needs for food and fibre of the mountain people, in addition to that of the plains population. The necessity of this arrangement partly originates from bad planning in the past. The buffer zone of adjacent *terai* and *bhabar* with thick cover of forests and marshy vegetation was converted into usable land in order to rehabilitate primarily refugee populations, subsequent to the division of the Indian subcontinent. The forests were alien to the culture of the predominantly agricultural population; consequently, they were altogether removed. This zone could have been used to alleviate increasing agricultural pressure in the mountains by shifting the population from the mountains in a regulated and gradual manner, although the eventual solution of population problems lies in checking population growth. That the problems of mountain degradation can assume far larger dimensions, compared to the refugee problem, was not realized by planners. The environmental problems partly lie in the fact that political leaders seldom think holistically. Political success has traditionally been best served by focus on problems immediately at hand (Cladwell 1984).

To summarize the landscape situation, more than two-thirds of the adjacent plains are under growth systems (croplands). In the mountains, the protective systems (mainly forests) occupy only 28.7 percent of the area; however, except for a small fraction of about 4.4 percent of the mountain area, the entire area of new-growth forests is dominated by a few sun-demanding early successional species and a large chunk of originally forested area now supports a vegetational structure far simpler, more stunted, and sparser than the original one. Consequently, it is of little protective or productive use.

The task of reviving the forest cover is becoming increasingly difficult. There is something wrong with existing development programs which seek to transform the subsistence economy into a cash economy, while the support system of the subsistence economy itself is on the verge of collapse. Consequently, crop productivity in the mountain region is on the decline (Khanka 1985), and efforts to replace native cows with higher milk-yielding cows at high government subsidies have failed (Jackson 1981, 1985).

A Case for an Alternative Form of Cultivation

The present situation calls for a major change in the development pattern: primarily the replacement of the crop system with the tree-farm system. The following reasons support this:

1. The crop system, though failing to meet the food requirement of the mountain people for even half of the year, leads to massive deforestation, which in turn is impairing the very support base of fodder and fuel, and water sources are becoming scarcer.

2. The present form of agriculture cannot be transformed into fossil fuel-powered agriculture primarily because of small land holdings and lack of irrigation.

3. Replacement of agriculture with horticulture also has overall limitations. First, the pressure on forests would not decline, for packing cases would be required to transport fruits, and fruit trees would not meet fodder and fuelwood needs.

4. Thus, the form of cultivation which is least dependent on natural forests is needed. This can be tree farming, as it can ensure the supply of fuelwood, timber, and fodder.

5. The net primary productivity even in unmanaged forests is several times greater than that of crop systems (Tables 4, 5 and 6), even in terms of commercial yields. Multispecies tree farms can be designed to utilize solar radiation most of the year, while in crop systems, solar radiation is not utilized much of the year.

6. Tree plantations involve far less soil disturbance than crop cultivation which requires frequent ploughing. Further, the amount of inputs per unit of production would be the least in tree farming. Deeper tree roots by promoting water infiltration and checking flow may prolong the life of springs, the major source of water to villagers.

7. Since tree cultivation does not need animal power, fodder which is largely derived from forests would be required in similar quantities. In that situation, the livestock population, which would primarily consist of milk-producing animals, would be reduced. Once motivated for quantity animals, villagers may adopt stall feeding, which is less destructive than grazing.

Prerequisites for the Model

In order to motivate people to adopt tree farming, it is supposed that the plains will meet the foodgrain requirements of the mountain population free of cost. There needs to be a mutualistic relationship between the mountains and plains, in which the plains will provide "ghost crop acres" for mountains and the latter, in a state of recovered forest cover, would save the plains from the hazards of floods, siltation of water bodies, and damage of productive croplands. Further, the entire region would be benefitted by the increased and relatively stabilized yield of outputs from forests, and by the revival of the eroded gene pool.

The other prerequisite involves expansion of private lands for farm forestry. Private forestry is preferred to community forestry in view of the well-documented tragedy of the commons (Odum 1983; Jackson 1985). At present, the size of cultivated land is about 0.8 hectare per household of six people. By distributing the land under damaged ecosystems (1,137,400 hectares, Table 2) to villagers, the size of tree farms can be made up to two hectares. The damaged lands also include original village forests, as well as the State Revenue Forests now denuded of tree cover.

Composition of Farm-Forests

Tree farms need to be developed primarily to meet the requirements of fuelwood for cooking, fodder for milk animals, and timber for village-level construction work. On the basis of relatively undisturbed stands of various types in the Central Himalaya, Rana and Singh (1984) reported an average net production of about 70 x 10^6 kcal per hectare per year, with about 45 x 10^6 kcal in woody components and 25 x 10^6 kcal in terms of leaves of woody species and herbaceous matter (Table 4). It is assumed the fodder requirement would be reduced to half of the present requirement subsequent to the replacement of agriculture with tree farms, as bullocks would no longer be required, and the dung production earlier needed to manure the fields would be minimal. In that case, the fodder requirement per household per year would be 19.2 x 10^6 kcal. The fuelwood and timber requirement per household per year amounts to 18.6 x 10^6 kcal. This total requirement of about 38 x 10^6 kcal can be met from slightly more than half a hectare of broad-leaf forest, such as oak forest (Table 4). In case the land available is severely degraded, it can be initially colonized by stress-tolerant and disturbance-adapted species like *chir* pine (Rao and Singh 1984; Nautiyal and Barbor 1985). However, *chir* pine forests would not provide tree fodder, although grass production would be greater than in broad-leaf forests (Saxena and Singh 1980). In order to meet the fodder requirements of the dry season when grasses are not available, additional land would be required to raise broad-leaf forests. However, these forests would take a long time to be ready for harvest, so until then, fast-growing native and exotic species need to be raised (Chaturvedi 1985; Dwivedi 1985) to meet the needs of the subsistence economy.

Each household can use the remainder of the two hectares of land for raising forests for commercial purposes. Depending upon the quality of land, availability of inputs, and the long-term ecological sustainability, multispecies tree farms can be raised to produce resin, timber, honey, paper pulp, medicinal products, etc. Studies are needed on management to maximize total output by making fullest use of diverse food chains that occur naturally. For example, from a multispecies tree farm, products as varied as fodder, silk-fibre, honey, and resin can be derived by designing an appropriate multi-foodchain model (Odum 1983).

The success of private tree farming would largely depend on the ability to develop a matching social system and management practices that are not only sound from conservation standpoints, but also require low inputs. Application of appropriate successional models, for instance, can facilitate attainment of management goals. Rosenberg (1984) has shown how the inhibition model of Connell and Slatyer (1977) can be profitably used for conservation and land-use management. This model proposes that any arriving colonist may establish itself, however, once established, a colonizer tends to inhibit the invasion of subsequent species. Normally, in order to exclude the invasion of undesirable species; one has to use biocides or hand-weeding, involving fossil fuel energy or human labor. According to the inhibition model of succession, desired species can be introduced so the subsequent successional sequence and replacement patterns are regulated.

Furthermore, it is possible to interrupt and regulate the successional sequence and rates, or to revert to earlier successional stages, with proper management practices. These management practices would minimize plantation work and other inputs. For instance, controlled herbivory may be used to stimulate vegetative reproduction of certain woody species, as there is evidence of herbivory initiating shoot growth (Dyer and Bokhari 1976; Barbour et al 1980). More than half of the woody species of the Central Himalaya are known to regenerate vegetatively (computed from Troup 1921) by coppicing, or through root-suckers and root-tubers.

A successful tree-farming program would not only conserve the land around villages, it would also keep the present forested area that accounts for 28.7 percent of the land free from biotic stress due to the local population, provided the present rate of population growth is reduced substantially.

Once the life-support systems are

repaired and basic energy needs of the people satisfied, limited and specific types of industrialization can be introduced to improve the economic level of the people. The industries need to be small and pollution-free. The components required and produced should be lightweight, and the water demand minimal. In order to minimize industry-associated increase in population pressure, it is necessary to introduce industries which maximize the use of services of the local population. It also calls for training the local youth to meet the requirements of the industries to be introduced.

Finally, we address the point of whether or not the above model is practically feasible. Preliminary studies relating to ecodevelopment in the area indicated that the villagers were willing to replace their cultivated land with tree plantations (Singh 1985). In this village, the literacy level was high, and a large percentage of the population was employed in the plains. The animal population has declined considerably from about 20 per household three decades ago to about six per household at present, partly in response to the decline in the availability of forest stock. All these factors in a cumulative way have led to the area under cultivation declining to less than half of the original size. It appears that people in the mountains are forced to bear the drudgery of the present non-viable agriculture, and would be ready to abandon this traditional profession provided appropriate and concrete alternatives exist.

Politically, it may seem difficult for the state to provide the necessary grain subsidy to the mountain population, but the state is already giving huge subsidies in various forms (e.g. cattle improvement, grazing and lopping rights in the state forests, provision of fuelwood and timber supply, subsidy of money for industries, etc.). It is possible that the burden of these subsidies and the maintenance costs of various defunct development agencies may amount to more than the cost of providing grain. Further, it may also be pointed out that the fossil fuel-based agriculture in the plains is being maintained at a sizeable subsidy from the state. In mountain agriculture, use of fossil fuel is negligible, and according to our model, the mountain people are going to be deprived of subsidy from the State Forests. The political problems associated with the grain subsidy can be solved by making people aware of the fact that the costs of environmental regeneration of the mountain region need to be considered as low ; the resources at stake belong to the mountains as well as the plains region.

USE OF ALTERNATIVE SOURCES OF ENERGY

For the protection of the Himalaya and sustainable ecodevelopment for the central region, it is imperative that alternative energy sources be found to achieve these goals. The level of per capita energy consumption in the hills is so low that it cannot be lessened further. At present, leaving aside some townships, almost total energy consumptiom of the villages depends on forest resources. Fuelwood contributes about 60 percent of the total energy in rural areas, including plains districts (Barthwal and Bhatt 1985); of this about 85 percent is used for cooking. Biogas has not been successful, and except for a few demonstration sites, it is seen nowhere in the hill regions. However, in Garhwal, the Nainidanda and Jharikhal blocks have some biogas facilities. Solar energy is mainly used for the natural production of biomass and to some extent for drying grains and household purposes. In effect, this source of energy has not been technologically harnesed. Although it is inexhaustible and, for the most part, available; does not damage land; has few problems of disposal and transmission; and is pollution free, some sociological and technological problems will always limit its use for cooking.

First, availability of solar energy may be erratic, and second, religious traditions regarding eating habits may stand in the way. Still, in places where firewood is scarce, solar cookers may be acceptable.

There has been a suggestion that to save fuel, pressure cookers should be supplied in the hills. If proper arrangements are made so that parts can be replaced and repairs can be done easily, we would advocate the use of pressure cookers at subsidized rates. Similarly, new types of **chullahs** manufactured by various agencies are being supplied at subsidized rates by the Uttar Pradesh government. It is claimed that whereas the indigenous **chullah** has an efficiency of 8 to 9 percent, the improved **chullah** (like **priyagini** which is not smokeless, but portable) has an efficiency of about 26 percent.[4] If supplied on a large scale, they can make an impact on the fuel consumption in the hill region, and will involve no social problems. Unfortunately,it is reported that unlike what is being done in the **terai-bhabar** region, the distribution of improved **chullahs** in the hill region is suffering from many setbacks due to organizational bottlenecks. The smokeless **chullah** has apparent advantages, but some people raise the objection that smoke helps maintain the quality of timber used in the household. We believe that this is a small problem which can be removed with extension work.

Although the yearly input of solar energy is reported to be about 7000 times more than the total human energy demand of today, which must also be true of the hills, solar energy cannot be used except in small amounts for cooking and pumping water due to several constraints. The alternative energy sources in rural areas need to be easily available, of lower costs than others, not too technical under present circumstances, and not far removed in use from local socioreligious traditions. It is for these reasons that women in some hill areas still prefer obtaining fodder and firewood rather than nonconventional alternatives 260 days a year (Barthwal and Bhatt 1985).

GeothermalEnergy

The Department of Nonconventional Energy Sources believes that geothermal power is likely to be the main, ifnot be the only, answer to energy needs of the hill areas of the country (Dayal 1985). Investigations of geothermal energy potential in some parts of U.P. are being conducted by the Wadia Institute of Himalayan Geology, the National Geographical Research Institute, and The Geographical Survey of India. No details are yet available, but except in Tapovan and Badrinath, the possibility of geothermal energy making any dent in energy consumption of the hills appears to be remote. For the present, all activities under the exploitation of geothermal resources are likely to be limited to research and development. Even if breakthroughs in technology are achieved and more sources of geothermal power are found, it is futile to hope that this will help solve the energy problem in any substantial way. It may, however, provide energy to remote places where both fuel and hydroelectric power would be difficult to supply.

Wind Energy

Energy available in the form of wind power is reported to be equal to four times the energy consumption of the world in 1985. Wind energy is available in plenty in the Central Himalaya and it is particularly abundant in the northern part, where fuel and electricity problems are acute. The Society of Science for the People (Jagdish 1985) has conducted *experiments to see the effect of slope on* wind speed, for example, which suggest that the combined effects of height and slope may make it easy to locate mountain sites which experience moderate to high wind in the Himalaya region. Unfortunately, little information is available on wind speeds in the region. Though the survey work is costly and time-consuming, wind speed data could be obtained by using Dines Pressure Tube Anemograph (DPT) at selected sites. After identifying the suitability of the site, wind farms (clusters of windmills), for power generation of the order of 1 MW can be set up at various places in the Himalaya region. This will reduce transmission costs, but as in the case of solar energy, the technological breakthrough is still awaited. National Aeronautical Limited (NAL), Bangalore is engaged in research and development of power generation through windmills. Alternatively, small windmills can be provided in many villages to do manual work like wheat grinding and to provide some light in the **Panchayat ghar** where people can gather and watch television or have social gatherings. Much is hoped for DNES in the matter of harnessing wind energy in the Himlayan region. Our estimate is that, presently, laying emphasis on harnessing wind energy will be more profitable than geothermal or even solar energy for remote places. The problem of storage of energy is acute here as well as in solar energy systems. Like solar energy, both wind and geothermal are clean, free of pollution, and have few transmission problems.

Biomass Fuel

Another way in which forest fuel can be saved is by using minor products of the *forest and fields. In the hills, the use of* such minor products for direct energy purposes is not popular. Although minor forest products like leaves are used as fertilizers, they have not been used in a form that can relieve the pressure on forest fuel. In large areas, the **chir** pine forests have abundant needles which are hard to degrade and are slightly acidic in nature. They are the main source of fire hazard in the Central Himalaya. In spite of considerable interest shown intermittently, this has not been put to use. It is true that with the help of the Indian Institute of Technology, Delhi, some fuel briquettes are being manufactured and are reported to be economically viable, but their use is confined to an extremely limited population. It would be interesting to evaluate the utility of this method of using pine needles for cooking purposes and consider the feasibility of mass production in a decentralized manner. In other words, if the method is found to be economically viable (or even nearly so) in a small cluster of villages, machines could be installed for supplying these briquettes to the villagers at a reasonable cost. Use of other forms of biomass, like sewage, sludge, gobar bagasse, etc., is not possible in the hills above 1000 meters or so, and is not dealt with further in this section. However, the use of pine needles as an energy source is not a sound ecotechnology, as depletion of nutrients from the forest ecosystem would destabilize its functioning.

Gobar gas is an appropriate source of energy below 1000 meters where fermentation can take place and both in Garhwal and to some extent in Kumaun region river valleys, **dun** valley, terai, and bhabar are making appreciable use of biogas. In statistical terms, there is a saving of three trees per family per year, and much time is saved in labor which women otherwise spend in fuel collection. With modification of techniques, biogas may be usefully produced at higher altitudes.

Microhydel

The exploration of microhydel units dates back to the British period. However, systematic exploration of microhydel generation was taken up only in the Second Plan for meeting local demands. It appeared that the microhydel projects were intended as a rapid solution to the problem of electrification, while the focus lay essentially on developing major power capacities (Joshi and Sinha 1981). However, in view of the capacity of available land and considerable objection to big dams, microhydels are essential for many areas.

Next to forest, the swift-flowing rivers (both snow-fed and those originating from the Lesser Himalaya) constitute the major resources for energy. Leaving aside major projects for hydroelectric generation on the River Kali, little use of the Bhagirathi and Jamuna has been made for power generation. There are various projects under consideration using both the technology of big dams and surface-flow tunnels. There is some opposition toward the big dams to be constructed in the hill region. The total generation capacity in the Central Himalaya may be around 20,000 MW. However, since all these cannot be easily harnessed due to difficulties in terms of site, power transmission, and cost, gravitation energy is being lost. A socioeconomic study of the implications of some microhydro power systems in the hills has been made by Joshi and Sinha (1981), and their report is not optimistic.

Since the power generated by microhydel stations is mostly used for lighting purposes, the maximum load is for several hours after sunset. There are no local industries except a few sawmills and flour mills, and in some cases pumpsets for irrigation. The chances of setting up of forest and agro-industries are remote and so far no worthwhile success has been achieved in these fields. The power generated the rest of the time is not used. It cannot be connected to the general grid on account of high cost. Further, microhydel power generation is more costly.

The smaller units require comparatively high running costs per unit of energy generation, as more human resources for management are needed than in bigger ones. Even for small units of 50 kW at least four persons are required to look after the unit according to the labor laws. The cost per unit of energy works out to be about Rs. 5.

The energy is utilized for a shorter time as there are no industries in the neighborhood which require power during the day. Furthermore, there are difficulties of repair and technical assistance at remote places and the water flow is not constant throughout the year. The administrative problems could be solved if the units are run by the village community where strict labor laws may not apply. One such example is in the village of Dasholi, in Chamoli, where the entire microhydel system is set up and run by the village community. The study of Joshi and Sinha (1981) shows that firewood consumption has not been reduced to any perceptible extent with the introduction of microhydel energy. However, the consumption of resinous pine sticks, or **chilka**, and kerosene, both of which are used for lighting purposes, has been reduced.

The search for renewable resources for energy is highly desirable for the survival of the population in the hills and for reducing the pressure on forests. Of the renewable low-cost technologies, microhydel power, in spite of the difficulties mentioned above, would be highly desirable provided changes are made in working and management. The untapped potential for microhydel is high, and suitable sites can easily be available. It would reduce transmission cost and be helpful to villages situated in remote areas. Today, electricity constitutes a small part of energy consumption by the rural household. There appears to be no hope for using electricity for cooking purposes in near future. Although we believe that in some cases where abundant supplies of surface waterflow are available and power cannot be used for any other purpose, it must be used for cooking purposes supplied at very cheap rates.

In brief, a decision on decentralization of energy production and distribution should be taken for meeting the energy demands of the dispersed hill population. As envisaged in the state's Sixth Plan (1980-85) such an energy system would have to be based on a systems approach. The available electrical energy in a given location may be utilized even in a nonconventional manner (e.g. besides flour mills, pumps, and sawmills, it may be given at cheap rates for preparing tea, beating water, etc.). The intermediate technology development groups in the country and elsewhere, such as in the U.K. (Khanha 1985) and BIT group in Nepal, have developed suitable microhydel plants and watermills. Possibly, these could be used even for power generation in springs and would be useful in small ways in the villages. In the name of development, the traditional watermills are being replaced by diesel flour mills. What is needed is an improvement in the traditional watermills. Small changes (e.g. in the ball bearing design of water turbines) would make a great difference in performance. But to encourage diesel machines by replacing renewable water resources is not a healthy development (Pant 1981).

Chapter VI of the U.P. Hill Development Seventh Five-Year Plan makes the interesting statement that not only for socioeconomic development of the hill region is power one of the most important infrastructures, but also it is required to reduce pressure on forests for fuel. High priority is given to accelerating the pace of power development, especially for rural electrification. However, no study project for household consumption to save fuel is envisaged. It is proposed that besides some tapping of nonconventional energy sources on a selective basis, soft coke, kerosene oil,and cooking gas will be provided by extending financial support. It is learnt that DNES proposes to set up Urja Grams (energy villages) on a large scale for using the best mix of nonconventional energy-saving procedures in order to improve the energy situation in villages. We hope that the Central Himalaya will be included in the program.

Progress during the Sixth Plan has not been implemented as well as planned and constraints which existed before still exist. However, Rs. 12.5 billion have been provided for power development of which Rs. 1.0 billion are for microgeneration hydel schemes in the Seventh Plan. It is not necessary to detail hydel and other nonconventional energy projects here. The emphasis on reducing the pressure on forests for fuel is a welcome aspect of the development plan.

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ENDNOTES

1. It is an irony that the chairman of the conference was the late Homi J. Bhaba of the Third World.
2. Personal communication.
3. This is assuming that the amount of tree leaves collected from forests mostly accounts for the difference between the values of manure input and sum of dung input plus fodder waste.
4. Personal communication.

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APPENDIX - I

1. The energy value of agronomic yield, 47.6 x 10^5 kcal per ha per year includes energy values for the yield of grain, pulse, and potato crops as given in the Government records (Uttar Pradesh Statistical book 1983-84). A value very close to it was obtained with an indirect method of computation. In this the average (48%) of several values reported for proportion of foodgrain imported in the region to meet the total requirement (Ashish 1983; Joshi 1983; Airy and Shastri 1984; Pandey and Singh 1984 a; ----- Jackson 1985; Singh and Negi unpubl.) was multiplied with total amount of foodgrain energy required by the population, to obtain the absolute amount of energy imported (40.3 x 10^5 kcal per ha per yr.). The total amount of foodgrain energy required was calculated by multiplying the minimum average across the population per capita per day foodgrain energy requirement, 2930 kcal (Pandey and Singh 1984 a) with total hill population. The amount of energy imported was subtracted from the total energy requirement to obtain the agronomic yield of 45.5 x 10^5 kcal per ha per yr. We also reached similar value of agronomic yield on the basis of amount of foodgrain imported in the mountain region of Nainital district (Food Corporation of India, Nainital Office, personal communication). The value of import for this region was used to calculate the total import in the mountain region of eight districts of Uttar Pradesh. Thus it appears that our value of agronomic yield, 47.55 x 10/5 kcal ha per yr must be close to the actual value.

2. For computing the crop byproduct energy, average ratio of agronomic yield to the byproduct energy reported for five villages by Pandey and Singh (1984 a) and Singh and Negi (unpubl.) was used. The amount of unharvested biomass, as reported by Singh and Negi (unpubl.) was used after appropriate adjustment to calculate the crop energy that returned to crop field.

3. Energy from forest is derived mainly to meet the fodder and fuelwood requirement. On average the livestock population per hectare cultivated land consists of 2.30 adult cattle, 2.20 young cattle, 0.76 adult buffalo, 0.77 young buffalo and goat or sheep* (a total of about 7, derived from livestock population of 1978 in mountain region and proportions of different categories given for an area of Kumaon Himalaya, see Jackson 1985). This size of livestock population is similar to that reported for a mid-mountain region (7.7 per ha; see Jackson 1985) and those reported

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1. It was assumed that one-third of the total sheep plus goat population is associated with settled agriculture. (6.01 and 8.36 per ha) for some village of mid-montane belt by Pandey and Singh (1984 a), and Singh and Negi (unpubl.). While estimating the fodder requirement, the population of stall-fed fodder (about 40%, Jackson 1985) diverted to manure was also accounted for.

4. While calculating dung production and assumption of 20% energy efficiency of dung production (Rogers 1983 in Pandey and Singh 1984 a) was followed. It was assumed that 80% of dung production is used as manure, and the rest villagers fail to collect.

5. The difference between the amount of manure input and sum of dung input plus unutilized fodder represented leaves collected from forest for preparing animal-bed, refuse of household and ash generated from fuelwood.

6. The per capita fuelwood requirement taken for this calculation was 1.61 kg (average of values given by Shah, 1982; Airy and Shastri, 1984; Singh and Negi unpubl.).

STATUS PAPER: NORTHEASTERN REGION

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INTRODUCTION

In race, language, culture, and social customs, the northeastern region of India may be said to be southeast Asia in miniature. In no other part of the country can such a large number of tribes be found living together, intermingled with an equally heterogenous group of non-tribal people; nowhere else do people speak such a vast range of languages and dialects and live such distinct and varied ways of life.

The region's 0.25 million km^2 make up about eight percent of the total geographical area of the country inhabited by a population of 26.6 million, which is 3.8 percent of the total population of the country. About 90 percent of the people, mostly tribals, live in rural areas.

Today, northeastern India is a political mosaic of five states and two union territories, bound together by economic interdependence. Recognizing this, the North-Eastern Council for the coordinated development of the region was formed in August, 1972. Its main function is to formulate and coordinate regional plans to supplement the Five Year Plans of the individual states and union territories. All the states of the region, except Assam and Tripura, are tribal states; even in these two states, the tribal populations constitute very sizeable proportions.

The region has the highest hydropower potential in India on account of the mighty Brahmaputra, the Barak, and their tributaries. This potential is estimated to be about 37,400 MW, which constitutes around 30 percent of the total hydro-reserves of India. Barely three percent of this has been harnessed so far. Efforts are being made to tap the hydel resources through the North-Eastern Power Corporation Limited (NEPCO), an organization set up in 1976 for this purpose by the government of India.

PHYSICAL SETTING

Topography

Physiographically, the region consists of three distinct divisions; the Assam or Brahmaputra Valley, the Meghalaya (Shillong) Plateau and the Northeastern Hills and basin, including the Arunachal Himalaya.

Climate

The great altitudinal differences in the region, together with the varied physiography, have made for great variations in the climate of the region.

The Himalaya ranges in Arunachal Pradesh have a typical temperate climate akin to the alpine zone. The area is abundant in temperate pine forests. At lower elevations are the Naga Hills, Mikir Hills, and Shillong Plateau (1300 to 2500 meters). The climate in these areas is mild temperate to sub-tropical. The Imphal Valley is mainly sub-tropical, while the plains of Tripura, Assam, and the southern part of Mizoram are mainly tropical. In the plains of the Brahmaputra and the Barak Valley, as in Tripura and western Mizoram, the average daily temperature in January is generally above 15°C. In other parts of the region the January temperature is between 10° to 15°; Shillong, however, has much lower temperatures. In July, the average temperature in the region except in Shillong and southern parts of the Mizo Hills ranges from 25° to above 30° C. During October, the daily mean temperature in the hills ranges between 20 ° and 25° C. In the Brahmaputra and Barak Valleys, in Tripura, and Western Mizoram, it is above 25° C.

The annual rainfall received in the region comes mainly from the southwest monsoon, between early June and September. The pre- monsoon showers begin in mid-April. The intensity of rainfall varies from place to place. The average annual rainfall in the northeastern part of Arunachal Pradesh, northwest of Bomdila, is above 4000 mm. This is reduced to the southwest. The southern slopes of Khasi and Jaintia Hills of Meghalaya receive only 2000 mm. However, the Cherrapunjee Mawphlang-Pynunsala belt, which is close to the southern fall of these hills, records 12,000 mm per year. The intensity of precipitation decreases towards the south of the region; Aizawl, the capital of Mizoram receives only 2000 mm, and Imphal Valley gets 1400 mm. However, in the hills of Manipur, the rainfall ranges from 4000 mm in the west to 2200 mm in the north. Tripura has an average annual precipitation of 2000 mm. Owing to the extended rainy season, the atmospheric humidity remains high almost throughout the year (Singh 1971).

Population

The northeastern region accounted for 26.6 million people (3.8 percent) out of the total population of 683.8 million in India in 1981. During the first half of this century, the country's population increased by 51 percent, while the population of the northeastern region increased by 140 percent. It is seen that the population increase in the northeast over these years has always been higher than that of the country as a whole. The rates of population increase from 1951 to 1981 for the country and the northeastern region have been 89 percent and 159 percent respectively. Table 1 below gives the population trends in the northeastern region.

The main causes for the high rate of population increase in the region are heavy immigration, which has been a feature of the region from early times; high natural rate of increase in population since 1921; and relative absence of mobility of the indigenous people of the region.

Immigration during the last five decades is often termed a 'prime cause' for the high population increase in the region. Between 1871 and 1901, the main and perhaps the only factor contributing to population increase in the region was immigration; natural increase in

Table 1: Population Trends in North Eastern Region

Census year	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura	Total for the Region	All India
		(Thousand Persons)							
1901	-	3,290	284	341	82	102	173	4,272	2,38,396
1911	-	3,849	346	394	91	149	230	5,059	2,52,093
1921	-	4,537	384	422	98	159	304	6,006	2,51,321
1931	-	5,561	446	481	124	179	382	7,173	2,78,977
1941	-	6,694	512	556	155	190	513	8,618	3,18,661
1951	-	8,029	578	606	196	213	646	10,268	3,61,088
1961	337	10,837	780	769	266	369	1,142	14,500	4,39,235
1971	467	14,625	1,073	1,012	332	516	1,556	19,581	5,48,160
1981	628	19,903	1,411	1,328	488	773	2,047	26,578	6,83,800

Provisional - Projected figures for 1981.

Sources - 1. Statistical Handbook, State Governments/Union Territory Administration
2. Series - 1. Paper 1 & 2 of 1981; Provisional Population Totals, registrar General and Census Commissioner for India

population was negative owing to widespread epidemics of ague, kalaazar and malaria.

A high natural rate of population growth began to be evident only after 1921. During the next 20 years, the natural growth rate in the region registered an average higher than the all-India figure. Even between 1951 and 1971, when there was a heavy influx of both refugees and others from East Bengal, the region registered a very high natural rate of growth in population.

Migration from rural to urban areas has been very pronounced during the decade 1971 - 81, especially in the tribal states of the northeast, showing a range of increase between 225 percent (over 1971) in Mizoram, and 39 percent in Tripura. There has also been a decrease in the percentage of rural population during this decade, except in Tripura, where it has remained around 89 percent over the decade. However, when compared to the all-India averages, the percentage of rural population in the northeast in 1981 (excluding Assam) is high, being 83 compared to 76 for India.

The northeastern region is land-abundant and population-scarce; the density of population is the lowest in the country. However, 'abundant' is misleading, for given the mountain terrain and the difficulties of settled cultivation in a large part of the region, the carrying capacity of the land is very small. Figures pertaining to population density and decennial poopulation growth rate are given in Table 2.

The distribution of population in terms of

Table 2: **Density, Decennial Growth Rate, and Sex Ratio 1981 Population**

State/Union Territory	Area x 1000 ha	Population 1000 persons	Density (Persons) persons/ha	Decennial Growth rate 1971 - 81 (%) Observed	 Adjusted	Sex Ratio Females per '000 males
Arunachal Pradesh	84	628	7	34.34	34.62	870
Assam	79	19,903*	253	36.09+	-	900
Manipur	22	1,411	63	32.57	31.83	972
Meghalaya	21	1,328	59	31.30	31.56	955
Mizoram	21	487	23	46.75	47.14	936
Nagaland	17	773	47	49.73	50.15	847
Tripura	10	2,047	195	31.55	31.81	948
Total	255	26,579	104	85.73++	..	909
All India	3,280	658,141	201	24.43	24.64	936

Source: Office of the Registrar General of India

*Projected: + Worked out from projected population

++ Estimated

economic classification is given in Table 3. The percentage of female workers does not lag far behind that of male workers in the tribal states of Arunachal Pradesh, Nagaland, Mizoram, and Meghalaya. In both Arunachal Pradesh and Nagaland, in fact, the female workers in the categories of cultivators and agricultural laborers show a higher percentage than the male workers in these categories.

ASPECTS OF CHANGE IN THE REGION

The natural resource to be exploited first by the British was the rich forest of the Brahmaputra Valley. This was done by the process of reserving forests as government property and the establishment of the Forest Department to manage them. Oil and natural gas were discovered in Upper Assam in 1926. These were developed, and they supplied a major portion of the oil requirements in India until independence in 1947.

Agriculture

Of the regions' total population , 90 percent is dependent on agriculture. The agricultural practices in the region are broadly of two distinct types: one practiced in the plains and valleys, and to a smaller extent on foothills and terraced slopes, known as 'settled cultivation'; and the other usually practiced on slopes of all possible gradients called 'shifting cultivation' or *jhuming* by the tribals of hill areas.

Settled cultivation accounts for about 14 percent (3.8 million hectares) of total geographical area, while shifting cultivation is practiced over 2.76 million hectares (Kaul 1981). The main foodgrain crops grown are paddy, maize, wheat, arhar, gram, and lentils, and among the

Table 3: Economic Classification of Population 1981

	Arunachal Pradesh	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
Total Population	628,050	1,411,375	1,323,343	487,774	773,281	2,047,351
Males	335,941	715,718	679,519	251,988	414,231	1,051,240
Females	292,109	695,657	648,824	235,786	359,050	996,111
Total Mainworkers	308,946	588,231	587,158	200,988	354,102	606,153
Males	190,238	334,178	360,260	123,815	207,495	515,746
Females	113,708	254,053	226,889	77,173	146,607	90,407
Cultivator	223,329	348,363	373,180	144,941	249,614	264,099
Males	113,378	203,301	212,839	79,422	116,390	229,585
Females	109,951	145,062	160,341	65,519	133,224	34,509
Agricultural Labourers	7,575	46,334	58,236	5,136	6,611	144,910
Males	5,240	22,396	33,154	3,023	4,578	116,045
Females	2,335	23,938	25,082	2,113	2,033	28,865
Household Industry Manufacturing Processing, Servicing and Repairs	1,267	64,071	6,403	2,580	5,079	9,836
Males	966	10,863	3,278	1,410	3,094	7,345
Females	301	53,208	3,125	1,170	1,985	2,491
Other Workers	76,775	129,463	149,339	48,331	92,798	187,313
Males	70,654	97,618	110,998	39,960	83,433	162,771
Females	6,121	31,845	38,341	8,371	9,365	24,542
Marginal Workers	21,336	61,305	19,912	16,830	64,573	53,898
Males	5,464	24,307	6,675	7,049	32,820	16,527
Females	15,872	36,998	13,237	9,781	31,753	37,371
Non-workers	297,768	761,839	721,273	269,956	354,606	1,387,300
Males	140,239	357,233	312,575	121,124	173,916	518,967
Females	157,529	404,606	408,698	148,832	180,690	868,333

Source - Directorates of Census Operations oilseeds grown are rapeseed, mustard, and sesamum.

The total production of foodgrains in the region was around 35 million tons in 1977 - 78 which came down to 29 million tons in 1979 - 80, against an estimated demand of 46 million tons. Production per unit area is low despite the fertile soil, well - distributed rainfall, and sufficiency of surface and groundwater for irrigation needs. One reason for this may be the practice of mono-cropping, especially of paddy; other reasons cited are the smallness of the area brought under high-yielding varieties (only about 20 percent of the cultivated area), and the low average per hectare consumption of fertilizer (approximately 5 kg). Irrigation facilities are available to only about 20 percent of the cultivated area. In addition, the per capita cultivated area is only 0.15 hectare; the all - India average is 0.24 hectare.

Shifting Agriculture

The other type of cultivation--shifting cultivation--is practiced by the tribal people of the area. This type of cultivation covers about 2.7 million hectares of land, of which at any one point in time only about 15 to 16 percent of the area is cultivated. It has been estimated that more than 0.45 million tribal families are engaged in shifting cultivation, with an average of 1.20 hectares of land to cultivate in a season.

The main characteristics of shifting cultivation are:

- rotation of fields rather than crops
- use of fire for clearing and preparation of land
- human labor as the main input, and non- of draught animal, plough or machinery
- use of simple instruments like dibble sticks, chopping knives, etc.
- shifting of homestead if necessary when new area is opened in distant places

Land under shifting cultivation is owned communally and fields are demarcated for successive annual operations with no permanent boundary, right of possession or ownership over land. The plots to be cultivated are jointly cleared of forests and brush up to stump level by the community in December-January and after burning the debris the families divide the land among themselves. After this division, labor on the individual plots is usually done by the individual or family. The crops grown are mixed and a variety of crops are raised on the same plot - paddy, millet, beans, sweet potatoes, tapioca, chillies, cotton, and vegetables. Mixed cropping has the advantage of ripening at different periods, thereby providing the tribes with varied food, six to eight months a year. Thus, the choice of crop is consumption- oriented (Goswami 1980).

The same plot of land is cultivated for two or three years, then abandoned for regeneration of soil fertility, and another piece of land within the village boundary is cultivated. The number of years of fallow depends upon the availability of land and population in a village. With increasing population, the cycle in most areas has shrunk from 30 or 40 years to an average of 5 to 8 years at present, which is hardly a sufficient period for rebuilding of soil fertility. The loss of soil due to erosion under this type of cultivation is also great, and has been estimated at 40 tons per hectare compared to 5 tons per hectare in terrace cultivation. It also causes reduction in organic carbon owing to burning. These losses have contributed to serious decline in the productivity of hill areas. They have also been cited as causes of heavy siltation in the lower reaches of the major river systems of the region, which has contributed to the heavy annual floods and inundation of large tracts of riverine land.

However, in some parts of the hill areas, and particularly in Nagaland, there are areas where improved and intensive methods of cultivation are in vogue. In the Angami area of Nagaland, irrigated terraced cultivation as early as 1841 was reported (Robinson 1841), described by Godwin-Austin in 1873 as "terrace cultivation of highest perfection seen in any part of the Himalayas". Similarly, improved methods of cultivation are found among the Apatanis in the Zero adjoining areas of Subansiri District, and Monpas (Tibetan race) in Kameng District of Arunachal Pradesh.

Forests constitute nearly 47 percent of the total area of the region. Arunachal has 62 percent of its area forested; Assam has 36 percent, Manipur 68 percent, Meghalaya 37 percent, Nagaland 17 percent, Mizoram 34 percent, and Tripura 58 percent. The reported area of land being utilized for forest in Arunachal is 5.64 million hectares out of a total of 8.36 million hectares of land. In Assam, the total area of 7.9 million hectares of land is reported as utilized. Details of land utilization in the different states of the region are given in Table 4.

Industry

Industrially, the region is extremely backward. If tea processing industry is excluded, the other major industries are few, excepting the oil refineries in Assam which have been set up recently. Besides these, sawmills numbered 25 in Assam in 1974-75. The classification of major industries is based on the criterion of employing at least 50 workers which use power or at least 100 workers without use of power. Employment was provided by such industries in Assam in 1974-75 to about 98,000 workers and income generated by them in that year came to Rs. 1030 million in Assam. For other areas, see Table 5.

Looking at the number of small-scale industries, the picture is more encouraging. Assam in 1978 had 3302 small-scale industrial units, while Manipur came second with 1481 units, followed by Tripura with 898 units. Table 6 gives details.

The key to the development of the region is mainly through the encouragement and further establishment of small and medium industries which have the required raw materials within easy reach for processing. Small-scale, mostly rural, industries have the general goal of providing the rural population with more opportunities for economic and social development and reducing the economic distance between the town and country to minimize migration, for

Table 4: Classification of North Eastern Region, Forest 1976-77

State/Union Territory	Geographical Area	Total Forest Area	Type of Forest	
			Merchantable	Unprofitable
	(hectares)			
Arunachal Pradesh	83,578	51,540	7,500	44,040
Assam	78,523	28,608	7,218	17,571
Manipur	22,356	15,154	15,008	146
Meghalaya	22,489	8,229	4,378	3,851
Mizoram	21,087	7,127	7,127	-
Nagaland	16,527	2,876	2,358	518
Tripura	10,477	6,028	4,925	1,103
Total	255,037	119,562	62,686	56,876
All India	3,287,780	*750,427	565,777	173,961

Table 4 (Contd.)

State/Union Territory	Classification of Forests			Ownwership			
	Reserved	Protected	Unclassed	Forest Depart-ment	Civil Autho-ritites	Corporate Bodies	Private individuals
	(hectares)						
Arunachal Pradesh	8,072	206	43,262	51,393	-	-	147
Assam	-	-	11,037	16,420	2,246	9,942	-
Manipur	1,377	4,171	9,606	15,154	-	-	-
Meghalaya	702	12	7,515	718	-	7,511	-
Mizoram	1,300	4,323	1,504	7,127	-	-	-
Nagaland	286	518	2,072	804	-	-	-
Tripura	3,946	2,082	-	6,082	-	-	-
Total	33,254	11,312	74,996	97,644	2,246	17,453	2,219
All India	*236,640	*119,027	699,218	18,782	20,219	12,000	

Source: Directorate of Economics and Statistics, Ministry of Agriculture

* Excludes data in respect of J & K for which legal classification of forest area is not available.

Table 5: Major Large-Scale Industries in Terms of Income Generated: 1974-75

Industry	Number		(Rs. in 100,000)				
	Registered Factories	Employment	Invested capital	Outstanding loan	Output	Income Generated	Employment
Assam							
Tea Processing	365	59,360	10,765	1,655	18,908	5,262	888
Sawing and Planning of Wood etc.	25	6,343	1,152	344	2,458	725	160
Railway Wagons and coaches etc.	3	3,574	48	-	484	179	167
Industrial Machinery for Food and Textile Industries	5	704	102	53	276	80	23
Cotton Spinning, Weaving etc.	3	1,280	221	215	275	65	45
Others	65	26,793	20,444	16,992	12,038	3,994	1,077
Total	466	98,054	32,732	19,259	34,489	10,305	2,360
Manipur							
Others	5	805	53	-	42	21	21
Total	5	805	53	-	42	21	21
Meghalaya							
Others	5	948	697	97	198	61	35
Total	5	948	697	97	198	61	35
Tripura							
Tea Processing	17	1,228	80	27	135	36	13
Repairs of Motor, Vehicle etc.	3	154	-	-	28	7	7
Electricity	8	359	-	-	13	1	16
Others	8	344	11	7	48	14	11
Total	36	2,085	91	34	224	58	47

Note: The annual Survey of Industries (ASI) census date covers all factories which employ at least two workers with use of power or at least 100 workers without use of power. Such factories account for about90 percent of the income generated in the entire factory sector.

(...) - Not available; - Nil. Source: ASI-1974 m Census Sector, Part III; CSO

Table 6: Medium and Large Scale Industries in North Eastern Region

(Numbers)

Industries	Arunachal	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
Sugar Factory	-	3	-	-	-	1	-
Paper Mill	-	3**	-	-	-	1*	-
Oil Refinery	-	3*	-	-	-	-	-
Jute Mills	-	1	-	-	-	-	1*
Cement Factory*		1	-	1	-	-	-
Hard Board	-	1	-	-	-	1*	-
Spun Silk Mills	-	1	1*	-	-	-	-
Cycle Factory	-	1	-	-	-	-	-
Distillery Project	-	1	-	-	-	-	-
Plywood and other wood products	2	13	-	1	2	1	-
Fertiliser	-	2	-	-	-	-	-
Chemical Industry (including Petro-Chemical)	-	12	-	2	-	-	-
Miscellaneous Industries	-	7	-	-	-	-	-
Total	3	48	1	4	2	4	1

Source: Report of the Study Team Industrial and Economic Development of the North Eastern Region (Vol. I Annexure XVII).

* Under construction (One in Assam)

** Two under construction

Spinning Mill under construction

example. Agro-based industries have both forward and backward linkages, the former meeting the demand for agricultural inputs and consumer goods and the latter based on locally available materials and human resources.

PRESENT ENERGY POSITION AND FUTURE PROSPECTS

The northeastern region has tremendous hydropower potential on account of the Brahmaputra, the Barak, and their tributaries. The hydel power potential has been estimated to be more than 20,000 MW. Vast potential for thermal generation exists; adequate coal, natural gas, and petroleum reserves are also available. With the current and planned generating capacities, there should be no shortage of electrical power and the potential for augmenting hydroelectric capacities is immense.

Energy Use: Domestic

As in the rest of the country, the energy-use pattern in the domestic sector of the region is still dominated by noncommercial fuels such as firewood, agricultural residues, and charcoal. Indeed, nearly 70 percent of the total energy consumption is accounted for by noncommercial fuels. This is because in the energy consumption pattern, the domestic sector predominates, and its requirements are met largely by noncommercial fuels. Marginal quantities of commercial fuels like coal, kerosene, liquid petroleum gas, and electricity are mostly used in urban areas. Industrial use of power in small quantities is presently found only in the populated areas of Assam and Tripura, and to a still smaller extent, in Meghalaya.

The energy need for domestic purposes is a very significant component of the energy matrix of society as a whole and is location-specific. The fuel efficiency of traditional devices for burning biomass materials is very low. It has been estimated that household energy consumption accounts for 40 to 60 percent of the total energy budget in southeast Asian countries where traditional fuels used are in abundant supply (Tinker 1981). Energy consumption for domestic purposes varies from region to region and also depends upon living standards and working conditions. For instance, it has been found that in Pondicherry region, irrespective of social class, the gross energy utilization in rural areas was much greater than in semi-urban and urban areas; cooking consumed 97 percent of the total energy in rural areas, 93 percent in semi-urban areas, and 90 percent in urban areas (Gupta, Rao, and Vasudevaraju 1979). The energy consumption per capita per day in rural, semi-urban, and urban areas was estimated to be 6880, 4002 and 3010 kcals respectively (ibid).

A study in biomass energy consumption for domestic purposes in Karnal revealed that as the size of the family increased, the daily average energy consumption per person decreased. The daily average energy consumption for each person in small, medium, and large families was estimated as 12,048, 8,438 and 7,647 kcals, irrespective of occupation. The daily average energy consumption for farmer and farm laborer, artisan, and village employee groups were 10,514, 9,144 and 8,473 kcals for each person, irrespective of family size (R. R. Gupta, Malik, and Jain 1982). No study on domestic use of energy in the northeast has been conducted.

Firewood

In the northeast, one of the most important daily needs in village life is firewood. Nearly 90 percent of the people depend on firewood as the only source of energy for cooking, providing warmth in cold weather, and even for domestic lighting, despite rich coal reserves in the region. The hill terrain and transport problems render the movement of coal and other commercial fuels extremely difficult. As long as the population remains predominantly rural, the transition to commercial fuels will take time. In addition, the low density of population, scattered villages, relatively abundant forests, and the general poverty of the people will make the change difficult. The progress of rural electrification has not been extensive enough to bring about any change in the energy-use pattern. Hence, dependence on firewood cannot be eliminated for many years to come.

Most of the hill areas in the region appear barren. This is usually ascribed to the practice of shifting cultivation, but it has also been claimed that, "firewood collection has a major share in the process of denundation of the hills - this is evident from the denuded hillocks ... where *jhuming* was not practiced" (Singh 1980).

Ecological degradation, which is widespread in the northeast, is primarily due to firewood collection without suitable planned provision for regeneration.

The annual requirement of firewood for a family has been estimated to be around 2 MT, roughly equivalent to 1.5 m^3. According to information available, most of the fast-growing species have a growing capacity of 20 m^3 per hectare per year, in which case, one hectare of firewood plantation might be sufficient to meet the demands of nearly 13 families. Since the fast-growing species like eucalyptus, populus, pines, albizzla, alnus, and nepalensis can be harvested in a cycle of four to five years, the actual area required for having an annual supply of 20 m^3 of firewood for 13 families would be four hectares. The size of the area in a village where firewood could be cultivated would depend on the number of families in the village. A rough estimate would indicate one hectare per four families, assuming a four-year felling cycle (Singh 1980).

At present, not more than two percent of the hill areas of the northeastern region are under annual cultivation, including shifting cultivation. The remaining area is officially classified as forest, but generally what really exists is either scrub forest, bamboo forest, or thatch grass. The potential for raising firewood is high and can easily be assessed. Firewood plantation can be taken up through a comprehensive program of social forestry. If "school education for children to grow and nurture trees and collect timber is carried out, and if small plants for compaction are installed which are maintained by local authorities through community efforts, and if some incentive is given for having forests well protected, the need for fuel and domestic lighting need not pose a threat to the timber availability in the forests"

(Chaturvedi 1984). The fuelwood plantation, therefore, would not only make the villages self- sufficient in firewood, but would also prevent wanton felling of valuable timber-yielding trees. In addition, erosion could be controlled.

To minimize deforestation resulting from large-scale use of firewood, Meghalaya launched a campaign a few years back to encourage the use of electricity for domestic purposes. Meghalaya has an excess of electric power. The campaign, however, was not a success. Firewood is freely available and any price paid for it is negligible when compared to the expenditure for the use of electricity.

Reserves of coal are large; coal is mined in fairly large quantities in Meghalaya and in lesser measure in a few hill areas of Assam. In urban areas and areas close to coal fields, coal is also used for domestic purposes. However, even in many urban areas of the region the use of coal is not as widespread as that of firewood.

The use of kerosene oil, for domestic purposes is slowly increasing in urban areas. In rural areas, however, the rate of increase in its use has rather slow. There is a slightly increased trend in towns like Shillong and Guwahati in the use of liquid petroleum gas for cooking purposes. With greater availability of LPG and increasing incomes, wider use is bound to occur.

Energy Consumption in Agriculture

If tea and sugar are considered industries, energy consumption in the agricultural sector is a very small proportion of total energy consumption. The energy required for agricultural purposes is mainly electricity for light irrigation and oil for tractors and pumps. Per capita consumption of electric power in the agricultural sector in 1977-78 for the states of Meghalaya and Tripura, for which data is available, is one unit per capita, as against the average of 16 units in India as a whole. Vast areas of land under cultivation in the region are unsuitable for the use of power-driven mechanical devices for sowing or harvesting. And in the hill regions, irrigation is rare, except perhaps in the terraced fields of the Angami region in Nagaland. The negligible use of power in agriculture is related to the terrain and the nature of agricultural operations in the region. In the areas of settled cultivation, where primarily wet paddy is cultivated, irrigation facilities are required, and pumpsets to lift water for irrigation purposes would eventually become the instrument of agricultural practice as the hoe is at present. With official recognition of the need to improve agricultural practices, increase foodgrain yields, use tractors, and improve irrigation, a substantially increased energy input in the agricultural sector is anticipated.

Industrial Energy Use

Per capita consumption of industrial energy is a major index of a region's economic progress. In 1977-78, out of a total of 111 units of per capita consumption of electric power in the region, the per capita share of industry was 43 percent. Out of this, Assam's per capita share was 27 and Meghalaya's 14; Tripura consumed three units and Arunchal Pradesh two, and Nagaland

and Manipur one each (Table 7). This is against the all-India figure of 62 units of per capita consumption of electric power by industry out of a total of 100, in 1977-78.

Table 7: **Per Capita Power Consumption 1977-78 and 1978-79**
(Units)

Station/Union Territory	1977-78 Domestic	Agriculture*	Industries	Total	1978-79 Total
Assam	3	Neg	27	35	36
Meghalaya	6	1	14	35	36
Nagaland	8	-	1	23	31
Manipur	4	-	1	5	12
Tripura	5	1	3	9	11
Mizoram	4	-	-	5	11
Arunachal Pradesh	5	-	2	9	9
All India	11	16	75	121	131

Source: Basic Statics, NEC, 1982.
* Utilised only. Total includes non-utilised also.

However, the main sources of industrial energy in the region are coal and petroleum products. The use of electricity as industrial energy is low. Apart from tea, petroleum and fertilizer are the major industries. Besides the Digboi, Guwahati, and Bongaigaon refineries, there is one at Namrup and another is expected to be set up in the private sector. A number of ancillary industries are growing around these units and are likely to increase. The expansion of the activities of the Oil and Natural Gas Commission (ONGC) and Oil India Limited, along with the expansion of the Namrup Fertilizer Plant and the operation of the cement factory at Cherrapunjee, would lead to an increase in the consumption by industry.

The cooperative jute mill at Silghat in Assam, and one in Tripura, produce hessian and sacking. Three sugar factories, (two in Assam and one in Tripura), three paper mills (two in Assam, one in Nagaland), two hardboard mills (one in Assam and the other in Nagaland), and other industrial units such as a cycle factory and distillaries in Assam have all been instrumental in increasing the demand for industrial energy. Schemes for the establishment of power tiller factories, more fruit canneries, pulp and paper mills, a nylon textile factory, and other industrial units are bound to increase the energy requirements of the industrial sector.

It has been estimated that by 1985-86, industrial energy would account for more than 50 percent of the region's total energy consumption. Coal and oil reserves would be more than sufficient to cope with the increased demands. And with hydroelectric projects in various stages of completion, energy requirements of industry should not pose any problem for the region. In the case of coal, known reserves amount to more than 1500 million tons while known reserves of crude oil and natural gas amount to more than 100 million tons and 50 billion m^3 respectively. With the earlier limitation on refining now removed, the availability of kerosene, aviation turbine fuel, furnace oil, and quality bitumen should be available in adequate quantities. And with the total installed capacity of 510 MW in both hydel and thermal power generation (as of May 1982) electric power should not be a constraint to rapid industrialization of the region.

The main bottleneck for industrialization is lack of adequate transport facilities. The expected increase in road, rail, and air transport will not pose any problem with respect to energy requirements of the transport sector in the region. In fact, the existing refining capacity in the region is enough to cope with the demand; power for the purpose of electrifying the railway system is also available in adequate quantities.

North-Eastern Electric Power Corporation (NEEPCO)

As mentioned earlier, the hydropower potential is estimated at 21,000 MW which constitutes 30 percent of the entire country's power reserve. There is also a very high potential for thermal power, estimated at 1500 MW. However, development of power in the region has lagged behind the rest of India. All possible steps should be taken to augment power generating and transmitting capacities. A great deal of improvement has been achieved since the beginning of the 1970s, especially after the establishment of the North-Eastern Council in 1972 and the setting up of the North-Eastern Electric Power Corporation (NEEPCO) in 1976. NEEPCO has been set up for efficient and integrated development of power: to plan, promote, organize, investigate, design, survey, construct, generate, transmit, operate, and maintain power stations in the entire northeastern region. The NEEPO was organized on the recommendation of the North-Eastern Council (NEC) as an Electric Utility Corporation by the government of India, to harness the enormous power potential of the region and for the planned development of power generation projects including transmission lines for evacuating power.

Prior to the First Five Year Plan, there were only 10 to 12 small hydropower stations in the region, with a total installed capacity of about 2.5 MW. By 1980, a number of hydro and thermal power schemes had been in various stages of implementation in the region, with an installed capacity of 295.2 MW hydropower stations and 332.5 MW thermal power stations; total generation was 627.7 MW. In 1982-83, the total installed capacity increased to 708 MW, and in 1983-84, it further increased to 874 MW. Taking all the hydro projects already executed by the state governments and in operation, those already commissioned by NEEPCO and the projected ones by all the agencies, the estimated installed capacity by 1987-88 is 1469.7 MW, of which 835.2 MW would be hydro projects and 634.5 MW, thermal projects.

The Eleventh Power Survey Report (1982) published by the government of India gives the following figures of the likely energy requirements in 1987-88 for the northeastern region (Chowdhury 1982).

Table 8: Energy Requirements in the Northeast Region for 1987-88

STATE	ENERGY REQUIREMENT in MkWh	PEAK DEMAND in MW
ASSAM	1994	391
MEGHALAYA	238	47.8
MANIPUR	129	31.9
NAGALAND	95	22.5
TRIPURA	164	38.4
ARUNACHAL PRADESH	47	14.9
MIZORAM	36	18.8

Source: NEEPCO News, July-December 1982, p.15.

An investment of Rs. 16.2 billion will be required for the five projects, which will enable generation of 1855 MW of power and 8760 million kWh of energy including projects already under execution or completely investigated. This will start giving benefits from the end of the Sixth Plan and will be completed by the beginning of the Eighth Plan, subject to the availability of funds.

The region has a terrain ranging from sea level to 20,000 ft. The hills and mountains are geologically very young and there are large formations of shale, sediments, etc. The northeast is a highly seismic area, with a history of major earthquakes.

The economic feasibility of large hydel projects and corresponding thermal projects need to be studied along with the technical feasibility of impounding large quantities of water within the limitations of the rock and soil characteristics of the region. This is to say, vulnerability to earthquakes and the nature of the soil and rock may impose great limitations upon hydel projects. There is need for continuous study of the interaction of reservoirs with the behavior of soil and rock formations. Such studies need to be both comprehensive and continuous. These possibilities also indicate the need for utilization of other energy sources.

Microhydel Projects

The northeastern region has not been able to benefit from electricity despite huge hydropower potential. Long transmission lines are difficult to construct and maintain in this hill and mountain region, calling for large investments and long gestation periods. The load requirement in the tribal villages is mostly for heat and light. Since there are numerous streams and rivulets flowing in the region, NEEPCO can take up microhydel schemes so these villages can be provided with power. This will enable provision of power to the villages in the shortest time.

Alternative Sources

In the northeast, as in the rest of the country, expectations of a better life have been rising since the First Five-Year Plan period. In recent years, this expectation has become much more pronounced among the tribal population. The need to provide relief to them is urgent. The large power projects under contemplation may not save these people living in sparsely populated and widely scattered villages. Alternative schemes need to be designed.

Theoretically, a large number of alternative energy systems are available. These systems are, however, location-specific. In order to adapt and apply their technologies to local situations, careful and detailed location-based surveys and experimental trials are necessary.

Solar Energy

Most of the northeast is cloudy throughout the year, except about 100 days between December and April and five days a month on an average the rest of the year. Large-scale use of solar modules may not be operative or economical in many areas of the region. In remote and inaccessible areas, solar energy for PV pumps, driers, and cookers could be tried to assess their success. Solar PV pumps of half to one HP can help small and marginal farmers to get irrigation and drinking water. In Tripura, one half-HP pump is being operated by solar energy, and it provides water to about three acres of land and helps five tribal families in getting five additional tons of foodgrain per year valued at about Rs. 13,000. A major portion of energy used in the villages is for cooking. It is possible to adapt solar cookers, which would relieve the pressure on firewood and release human energy for more productive work. It is reported that Arunachal Pradesh is setting up a solar timber- seasoning kiln, expected to give 15 to 20 percent more yield per annum. Investigation and experimental trials would be required before large-scale use of solar energy could be tried in remote areas of the region.

Biogas

Another energy system which could be adapted to the conditions of the region, helping villagers to be more self-reliant than if they were to use electricity or other commercial fuels, is biogas. The livestock population of the region is estimated at more than 1.5 million (1979 figure). More than 250 million ft^3 of gas could made available for cooking, domestic lighting, and even street lighting, from the utilization of only 30 percent of the waste of this livestock population.

Besides the livestock waste, the region has other waste material: agro-waste, forest waste, and plants like water hyacinth which are good raw materials for biogas production. Furthermore, the kind of technology for this purpose that would be 'appropriate' for the region is available.

Another proposal sometimes made is to experiment with windmills to ascertain their feasibility for irrigation purposes, as well as for domestic and community use. The average wind energy density (with velocity of 3 to 6 km/h) in many areas of the region is estimated to be sufficient to operate low-speed windmills.

These alternative sources of energy for the northeast involve a high element of risk; the relevant technologies are unknown here, and it would be necessary for the state to undertake a considerable number of pilot projects. Even with a large number of pilot projects, the distances between villages and the difficulties of communication might hamper the demonstration effect. Capital is also a constraint, though help from the Department of Non-Conventional Energy and the Rural Electrification Corporation could be sought, not only for undertaking pilot projects, but for popularizing extensive use of projects which prove feasible.

Coal

Coal deposits are found in abundance in the hill areas of the region: Khasi, Jaintia, and Garo Hills of Meghalaya, Mikir Hills, Langlai Hills, and Dissoma Valley and Kallaini River Valley. It also occurs in Koilajan in Koila Pahar.

In Khasi, coal is found in various places, the more important coal fields being at Langrin (extreme southwest of Khasi Hills), Um-Rileng, (6 km northwest of Shillong), Mawbehbaker (25 km south of Shillong), Mawsynram (16 km north of Shella) Mawlong, Laiteryngew (near Cherrapunji) and Langkyrdem (near Pynursla). In Jaintia Hills, coal is found at Jarain, Bapung, Sutnga, and Lakadong.

In Garo Hills, the coal seams found in Baljang, Doiring and Waimng are very good quality. The Rongrengiri coal fields in Simsang valley, about 16 km east of Arbela, and 25 km east of Tura, have a vast area of nearly 30 km^2. However, at present the coal seams are rather thin. Another coal field in Derangiri, extending eastwards into the Nongstain area of Khasi Hills, has a reserve of about 125 million tons.

A small quantity of coal mined in these regions is sent to Shillong and is used as domestic fuel. The bulk of the quantity of coal is supplied outside the state for railways, industries, and steamers. As firewood supply is likely to diminish in the future, the use of coal as domestic fuel will increase. In many areas of the region, coal is found on the surface and need not be mined. This enables the villagers to collect coal and use it for daily use. In areas near Cherrapunji, coal is used daily, while in Shillong, its use is greater during cold seasons.

Rural Electrification

Rural electrification is one of the 20-point programs. In some districts of what used to be Assam, electrification of villages in a number of districts had already been started in 1960. It was then undertaken in an ad hoc manner with no particular attention to the wider socioeconomic aspects and the development of rural areas. As a consequence, no worthwhile progress was recorded before the beginning of the seventies.

In Meghalaya, a rural electrification scheme was begun only in 1971-72, when the Rural Electrification Corporation (REC) sanctioned grant and loan finances for the purpose. By 1975, two REC-financed schemes were in operation, covering 63 villages. By June 1985, 56 schemes were at different states of execution in 1978 villages out of a total of 4583 villages (according to the 1971 census). The number of villages electrified in 1975 was 185; ten years later, in 1985, this number increased to 1284; that is, 28 percent of the villages in Meghalaya are electrified.

A few constraints hinder speedier implementation of the scheme; shortage of technical manpower, such as engineering staff at different levels; lack of surface communication facilities; inadequacy of funds; and slow load-growth resulting in huge recurring loss in rural electrification works.

The electrification of rural areas has as one of its major objectives the socioeconomic goal of providing a measure of the modern facilities of life to the vast majority of people living in the countryside, and to help in increasing income, employment, and productivity. It is also expected to act as a safeguard against the vagaries of the monsoon, by ensuring sustained supply of irrigation water efficiently and economically from village wells by the use of electrically operated pumpsets. In fact, rural electrification is said to constitute the backbone of the ground water development program by ensuring availability of cheap electric power for operation of wells, tubewells, etc.

Out of a total of 23 million hectares of ground water developed by 1980-81 in the country, the share of the northeastern region is negligible. The estimated ground water irrigation potential in Assam of about 0.7 million hectares (6.8 percent) were brought under irrigation by 1980-81. In Tripura, out of an estimated 15,000 hectares of ground water irrigation land potential, only 5500 hectares have been brought under this kind of irrigation. In the other states of the region, land under irrigation is either non-existent or extremely negligible except in Meghalaya, where of a potential 15,000 hectares, 6100 hectares are irrigated by ground water.

Besides the impact of rural electrification on agriculture, it has also helped the development of rural-based processing industries. Studies made by REC have indicated that after electrification, the number of small agro-processing units increased nearly five times in selected areas. The number of industries after electrification ranged from 0.8 per village in backward areas to about two per village in the advanced areas. In most of the states, the existence of such agro-processing units has come to depend more on the locally available inputs than on outside factors.

In the states of the northeastern region, electric power is now contributing to the development of important rural artisan trades such as weaving, embroidery, willow wickers, and bamboo and wooden toys. New employment opportunities have also been generated, the number of persons employed varying from one to five per industrial unit depending on the nature of the small unit and the caliber of the electric motor and its utilization.

It has also been found that rural electrification has contributed to an improvement in rural lifestyle. The use of electricity has further popularized radio (and in some areas cinema) as entertainment. It has helped to minimize human drudgery in agricultural occupations and has opened avenues to have workshops, schools, and dispensaries. The shift to power-driven pumpsets has reduced the time required for lifting ground water from eight to four hours per acre, compared with manual operation, thereby allowing farmers to pursue other occupations.

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ENERGY FLOWS AND SHIFTING CULTIVATION

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INTRODUCTION

The increasing agricultural yields of the last few decades in parts of India were possible through industrialization of agriculture, involving large fossil energy subsidies, heavy fertilizer application to the soil, sophisticated chemical control measures to reduce pest and disease infestation, and above all, high-yielding crop varieties. Such agricultural systems are efficient in terms of human time and labor inputs, but are highly inefficient from an overall energy point of view, as five to ten units of fuel energy are required to produce one unit of food energy (Steinhart and Steinhart 1974). The obvious inapplicability of such systems as models of development in an energy-limited world has led to renewed scientific interest in traditional systems of agriculture and traditional rural ecosystem organization and function, as these are considered to offer greater ecological efficiencies.

In particular, shifting agriculture, variously termed as "swidden" and "slash and burn" agriculture (more popularly known in India as *jhum*) has been held up as a model of productive efficiency where five to fifty units of food energy are harvested for each unit of energy put into the system (Rappaport 1971; Steinhart and Steinhart 1974; Mishra and Ramakrishnan 1981; Toky and Ramakrishnan 1982). It has even been considered possible to have increased crop production without departing too much from this traditional system (Greenland 1975; Revelle 1976; Mutsaers et al 1981; Ramakrishnan 1985b), which has been called the most evolved system for the forested areas of the humid tropics (Conklin 1957; Carneiro 1960; Nye and Greenland 1960; Walters 1971; Ramakrishnan 1984a). This land-use system has been considered viable only when the population density is one person for every four hectares of land. At higher population levels, degradation of soil and vegetation occur due to shorter fallow periods, making this agricultural system ecologically and economically non-viable. The present paper concentrates on these aspects, with emphasis on energy flow, and looks at possible modifications in the system to restore the ecological balance that now stands distorted in the northeastern hill region of India.

THE *JHUM* SYSTEM

Jhum is an important land use in the tribal areas of India. It is extensively practiced in the northeastern hill region along with restricted valley cultivation of rice on flatlands. It is also prevalent in parts of Orissa, Madhya Pradesh, Maharashtra, Andhra Pradesh, and in the Western Ghat region of peninsular India.

Man and Land

Generally speaking, the population in most of the northeastern states slightly more than doubled in the first fifty years since the turn of the century. Similarly, it almost doubled in most states between 1951 and 1971.

In the northeast, *jhum* is estimated to have covered about 425 x 10^3 families according to 1971 census data. At a growth rate of 25 to 30 percent, this would now be about 547 x 10^3 families, likely to rise to 766 x 10^3 families by the turn of the century (North-Eastern Council 1982). If the projections given by Myers (1980) are interpreted into the northeastern situation, 0.55 million families at present have cleared about 6000 km^2 of additional forest for *jhum*, of which half would be primary forest.

The exact area under *jhum* in the northeast is not known. The area under *jhum* in 1971 (Table 1) has been determined on the basis of the average *jhum* cycle for a given state and the number of families involved. However, such an average is misleading as the length of the *jhum* cycle is dependent upon the population dispersion. Thus in Meghalaya, though the average *jhum* cycle is assumed to be a little over five years for this calculation, there are locations where the *jhum* cycle has even come down to a 0-year cycle (slash and burn of what grows during the intercropping winter fallow phase)! The data so calculated does not account for the land taken over by weeds or completely desertified, and therefore rendered useless for agriculture. Though we have identified a variety of patterns in the *jhum* system based on ecological conditions and the socioeconomic and cultural background of the tribals, what is discussed here is based on two major patterns of *jhum* in the region, studied in depth in Meghalaya. The typical *jhum*, widely practiced except for the variation in cropping pattern and the type of vegetation slashed and burnt, involves clear-cutting of the vegetation, followed by burning and subsequent cropping for a year or two on steep slopes of 30° to 40° angle without any elaborate preparation. This is exemplified by the low-elevation *jhum* system of Meghalaya (Toky and Ramakrishnan 1981a). A modified version involves selective felling of vegetation and elaborate preparation of the land, followed by a controlled burn before cropping for a year or two, as practiced at higher elevations of Meghalaya (Mishra and Ramakrishnan 1981).

The Low-Elevation System

During the winter months of December and January, the undergrowth is slashed and small trees and bamboo are felled by families (with an average size of two adults and four children) covering an area of 2.5 to 3 hectares. If the vegetation is dense and more labor for clear-cutting of the plot is required, this is done as a cooperative venture involving other families. Larger trees are often left behind along with stumps of smaller trees which help in faster regeneration of vegetation during the fallow phase subsequent to cropping.

While larger tree trunks and bamboo are taken out for construction and maintenance of huts, or even for export outside the village boundary for monetary return, some of the wood is also used for cooking fuel. Before the

Table 1: **Area under *jhum* based on data of the North-Eastern Council , 1971**

		Area under jhum (X 10^3 ha)			
	Geographical	Annual	% geogr.	Total	% geogr.
Arunachal	8149	92	1.13	248	3.04
Assam Hills	1535	70	4.56	498	32.44
Manipur	2236	60	2.68	100	4.47
Meghalaya	2253	76	3.37	416	18.46
Mizoram	2108	62	2.94	604	28.65
Nagaland	1649	74	4.49	608	36.87
Tripura	1067	23	2.16	221	20.71

onset of the monsoon, toward the end of March or early April, the dried slash is burnt in *situ* after making a fire line around the *jhum* plot. After repetitive burning as required, a seed mixture of cereals, legumes, vegetables, and tuber crops are sown together. The crop mixture may vary from seven to thirteen depending on the *jhum* cycle (Table 2) and is harvested sequentially from July to December as the crop matures. Often, the placement of the crop on the slope has a pattern which can be related to the photosynthetic efficiency of the crop cover in the system, and to the nutrient uptake and use-efficiency of the crops. Thus, crop species with high nutrient-use efficiency are placed at the tops of slopes while slope bottoms are a sink for nutrients washed down from the top (Ramakrishnan 1984a). The objective of the farmer is to optimize production in a situation where the nutrients are in a state of flux due to high rainfall and steep topography.

A shift toward tuber and perennial crops, rather than cereals, is noticed as a consequence of shortening the *jhum* cycle. (The length of the intervening fallow phase of natural vegetation before the same plot is cropped again.) This shift can also be related to the high nutrient-use efficiency of these crops in more infertile soil under a shorter *jhum* cycle.

The High-Elevation System

The high elevation *jhum* system is a modified version of the typical one in that the slashing of the vegetation is only partial. While the shrub and herb species in the plant community are clear-cut, only the lower branches of the sparsely distributed pine trees are cut. Elaborate ridges running down the slope are made, using the slash arranged in parallel rows and topped with a layer of soil after it has dried so that the burning is controlled. The furrows are highly compacted and act as water channels. Apart from preventing water-logging which is important for potato cultivation, the water flow through compacted furrows also helps check losses. These modifications could be partly related to the cropping pattern

Table 2: Crops grown and yield in the *jhum* plots at lower elevations in Meghalaya (after Toky and Ramakrishnan 1981a)

	Total economic yield (kg ha - 1 yr - 1)		
	30 yr	10 yr	5 yr
Grain and seed			
Oryza sativa	1161	378	66
Sesamum indicum	446	541	25
Zea mays	770	397	30
Setaria italica	193	23	9
Phaseolus mungo	10	-	-
Ricinus communis	5	-	-
(20146)	(6318)	(753)	
Leaf and fruit vegetables			
Hibiscus sabdariffa	44	139	96
Hibiscus esculentus	-	50	-
Capsicum frutescene	-	1	-
Lagenaria lencantha	140	81	-
Cucurbita maxima	62	-	-
Cucumis sativa	16	-	-
Momordia charantia	-	5	-
Musa sapientum	-	105	-
(657)	(5679)	(16182)	
Tuber and rhizomes			
Manihat esculenta	338	1352	690
Colocacia antiquorum	260	294	180
Zingiber officianalis	10	-	-
(1043)(2712)	(1556)		
Silk worm			
Cocoon (silk)	4	-	-
Pupae (without cocoon)	0.2	-	-

Total plant (Kg ha - 1 yr - 1) is given in parenthesis

and the need for conserving nutrients in the deficient acidic soil of a cold climate. Root and tuber crops such as *Solanum tuberosum*, *Ipomoea batatas*, *Colocasia antiquorum*, cereals such as rice and maize, and a few legumes and vegetable crops are all grown together in the mixtures. Under shorter *jhum* cycles, the number of crop species in the mixture is reduced.

Species Diversity and Stability

Mixed cropping with high species diversity ensures a high degree of stability by: high photosynthetic efficiency through a multilayered canopy organization; efficient nutrient use through a stratified root profile in the soil for the use of nutrients from all depths avoiding competition; acting as biological pest suppressant (Litainger and Moor 1976) through native species which have highly developed natural chemical defense systems (Janzen 1973) and keeping any given pest population under control through genetic diversity in the crop mixture; an efficient crop cover to conserve losses through hydrology (Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a).

Once a crop species is harvested, it leaves space for the next crop at its peak growth and thus contributes to optimize resource use. A characteristic feature of the *jhum* system is the high accumulation of biomass in relation to the actual economic yield (Ramakrishnan 1984a). Such high biomass production ensures stability of the system through efficient cycling of nutrients. Without this addition of organic matter, it would become necessary to depend upon costly inorganic fertilizer that is hard to procure and of questionable effectiveness under high temperatures and rainfall of the humid tropics (Gleissman 1980; Gleissman et al 1981; Ramakrishnan 1984a). Inefficient fertilizer use is accentuated by the uneven topography of the hills and the thin and highly porous sandy soil of the mountains (Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a) which result in heavy losses from the crop system (Table 3), particularly before the crop cover is established and during harvest (Fig. 1) thus contrasting with the drastic reduction in losses through hydrology from a 5 year-old fallow. In the high elevation *jhum* system, 0.6 to 0.8 kg ha^{-1} of nitrogen is ploughed back into the system through non-edible crop biomass (Table 3).

Modern agriculture considers weeds totally undesirable and, therefore, has developed technology for their total eradication from agro-ecosystems through mechanical, chemical, and biological means. However, there is growing realization that weeds to a certain extent are desirable and may play an important role in agro-ecosystem management. This "non-weeding" concept is an essential ingredient of traditional *jhum* (Saxena and Ramakrishnan 1984; Mishra and Ramakrishnan 1984) and similar systems elsewhere (Chacon and Gleissman 1982). In the *jhum* plots of northeast India, weeding is never total; the residual weed population has a role in conservation of soil and nutrients that may otherwise be lost through hydrology (Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a). Even the weeds removed are put back into the *jhum* plot itself. Thus, the return of an element such as nitrogen through weed biomass recycling in a high-elevation *jhum* system may range between 0.8 to 3.5 kg ha - 1 (Table 4).

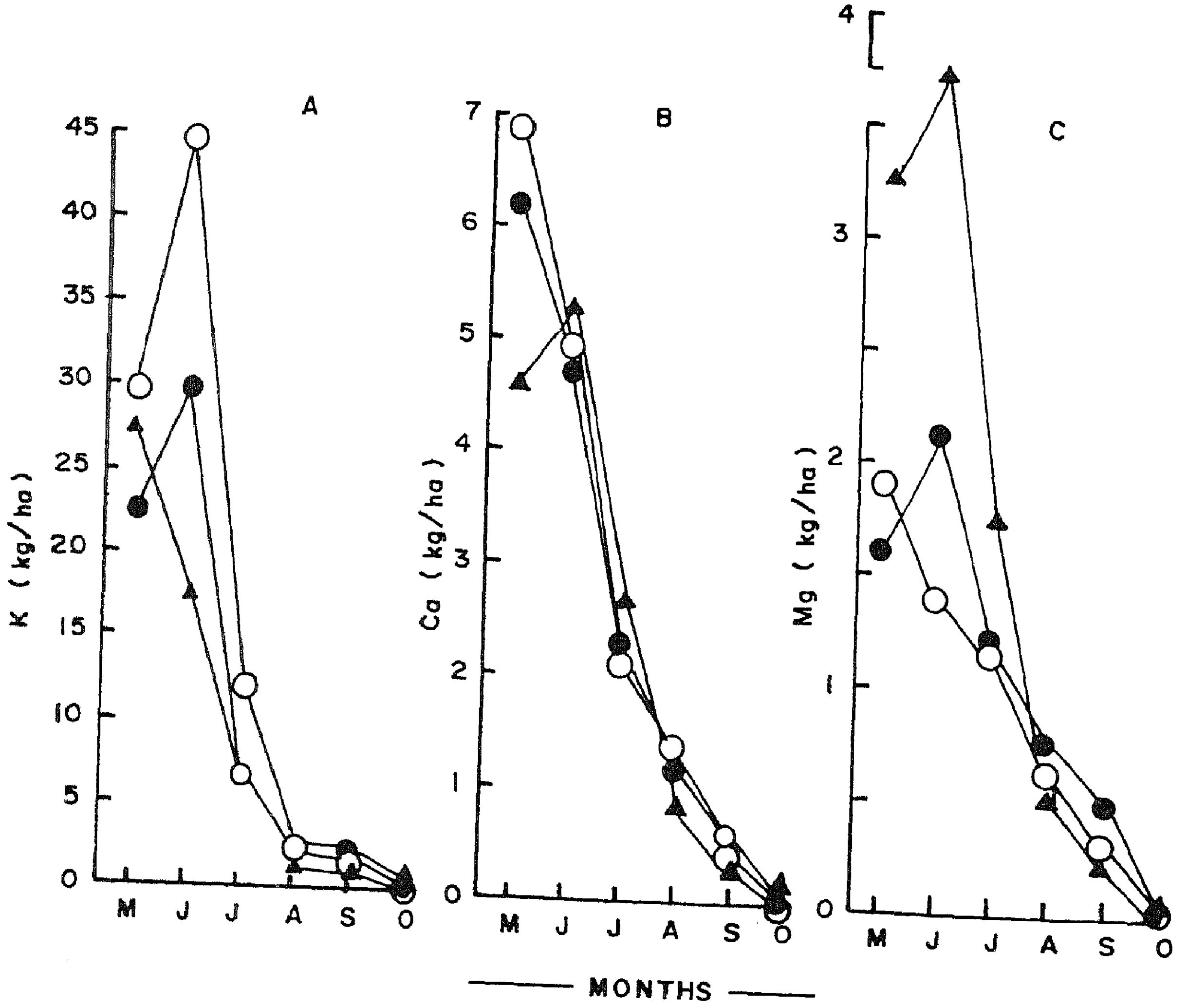


Fig. 1. Monthly loss of potassium (K), calcium (Ca) and magnesium (Mg) in percolated water during the monsoon at the time of cropping after the burn in sites under 30-(●), 10-(○), and 5-(▲) year *jhum* cycles (after Toky and Ramakrishnan 1986b)

Table 3: **Nutrient losses (kg ha - 1 yr - 1) through run-off and percolation water under 10 - yr *jhum* cycle agro-ecosystem and a 5-yr fallor (after Toky and Ramakrishnan 1981 b: Mishra and Ramakrishnan 1983 a)**

	10-year cycle *jhum* plot		5-yr fallow	
	Run-off	Percolation	Run-off	Percolation
Low-elevation *jhum*:				
Nitrate nitrogen	4.2	10.7	0.8	1.1
Available phosphate	1.3	0.1	0.1	0.02
Potassium	91.2	21.2	0.9	0.5
High-elevation *jhum*:				
Nitrate nitrogen	1.7	0.5	1.0	0.9
Available phosphate	0.9	0.1	ND	ND
Potassium	80.1	25.8	19.6	ND

ND - Not detectable.

Table 4: **Nitrogen input: Output Budget (kg ha - 1 yr - 1) for different *jhum* systems (after Mishra and Ramakrishnan 1984)**

	Fallow cycle (yr)			
	15	10	1 yr crop	11 yr crop
Inputs				
Precipitation	3.6	3.6	3.6	3.6
Slash	43.6	18.6	29.3	-
Organic manure	-	8.4	14.0	25.9
Inorganic fertilizer	-	-	0.7	1.4
Weed ploughed back	0.8	2.6	3.5	3.4
Byproducts ploughed back	0.8	0.6	0.6	0.3
Total	48.8	53.8	51.7	34.6
Outputs				
Fire	510.2	462.1	262.8	-
Sediment	119.1	128.5	172.9	176.3
Run-off	1.30	8.0	8.2	10.0
Percolation	0.9	0.5	0.8	0.7
Weed removal	4.0	13.0	17.3	16.8
Total	690.5	643.6	482.4	213.5
Net difference	641.7	589.8	430.7	178.9

Dash represents absence of that input/output from the sytem.

LAND USE AND ECONOMIC EFFICIENCY

A sweeping statement often made is that the *jhum* system is not economically viable and therefore should be abandoned in favor of settled terrace cultivation on hill slopes. Lack of reliable data has hindered looking at this problem in a systematic way. Available studies have not defined parameters such as *jhum* cycle, crop mixtures, or conversion values used for calculation when comparing different crops in terms of rice yield, as rice was only one of the crops in the mixture. It is therefore not surprising to find rice yield values as low as 190 kg/ha (Borthakur et al 1978) and as high as 1200 kg/ha on the other extreme (Misra 1976). Therefore, comparative estimates of yields under different *jhum* cycles at low and high elevations and evaluation of this land use vis-a-vis sedentary farming, such as terrace and valley cultivation (Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan 1981), become meaningful.

The actual yield for individual crop species was obtained for 30-, 10-, and 5-year *jhum* cycles for the low-elevation *jhum* system (Toky and Ramakrishnan 1981a) and for 15-, 10-, and 5-year cycles for the high elevation *jhum* system (Mishra and Ramakrishnan 1981), making it possible to compare economic input and output (Table 5). A few conclusions from this study were: a longer *jhum* cycle gives better yield than a short cycle; a 10-year *jhum* cycle is economically viable; though terrace cultivation gives as much return to the farmer as *jhum* under a 10-year cycle, a major fraction of input for the former is through inorganic fertilizer while labor is the chief input into *jhum*.

Though terrace cultivation provides annual sustained yield, the life of terraces in the region often is not more than six to eight years, partly due to wash-out by heavy rains, damage to the soil, and high weed potential, leading to eventual desertification. Valley cultivation of rice has the advantage of sustained yield without the need for additional input of fertilizers as the valleys hold the nutrients washed down from the hill slopes.

When one compares *jhum* of the low elevation with the high-elevation system (Table 6), one finds that the net return from the *jhum* plot under a 10-year cycle is about six times more for the high elevation system. This is related to the better returns from potato cultivation, emphasized here at the expense of cereals, both under long and short *jhum* cycles.

The main advantage of the *jhum* system is that it meets the diverse needs of the tribal farmer, such as cereals, vegetables, tubers, and even fibre from the same plot, allowing self-sufficiency if the yields are maintained under a *jhum* cycle of 10 years or more. Besides, mixed cropping is an "insurance policy" in that some crops are likely to give good returns even if there is partial or complete failure of others.

ENERGY RELATIONS

Jhum in the northeastern hill region of India has survived chiefly because of the high energy efficiency of the system associated with longer *jhum* cycles where the only energy input is human

Table 5: **Monetary Input-Output (Rs. ha - 1 yr - 1) into *Jhum* Terrace and Valley Agro-ecosystems (after Toky and Ramakrishnan 1981a)**

	Jhum (year)			Valley	
	30	10	5	Terrace	Crops I
Input	2616	1830	896	2542 (4544)	4843
Output	5586	3354	1690	3658	3565
Net gain/loss	2970	1524	794	1116 (-886)	722
Output/Input	213	1.83 (0.80)	1.88	1.43	1.14

Table 6: **Monetary Input-Output Analysis of *Jhum* under a 10-yr Cycle at Lower and Higher Elevations of Meghalaya (after Toky and Ramakrishnan 1981a; Mishra and Ramakrishnan 1981)**

	Low-elevation *Jhum*	High-elevation *Jhum*
Input	1830	3842
Output	3354	14171
Net gain	1524	10329
Output/Input	1.83	3.9

labor provided by the farmer from within the family unit. According to Rappaport (1971), the Tsembaga people of the New Guinea highlands obtained an average of sixteen units of food energy for each unit of human energy employed during farming; this may increase to twenty under more favorable conditions. Others have reported equally high or even higher efficiency values with input/output ratios of up to 54 (Lewis 1951; Norman 1978; Uhl and Murphy 1981).

Input/Output Patterns

Most studies, however, do not mention the length of the *jhum* cycle or its relationship to energy efficiency. The present study of three *jhum* cycles gives different energy input and output patterns and overall efficiency values. Labor, the only input into the *jhum* system, is highest under a 30-year cycle and lowest under a 5-year cycle, with a 10-year cycle falling in between. Of all agricultural operations, slashing vegetation involves the highest energy expenditure ranging from over half of the total input under 30- and 10-year cycles to 16 percent under a 5-year cycle. This is because of the presence of larger species--shrubs, bamboo, and trees--under longer cycles, compared to predominantly herbaceous vegetation under a 5-year cycle. Labor input for weeding increased with shortening of the *jhum* cycle due to increased weed potential under shorter cycles (Saxena and Ramakrishnan, 1984). The labor input into thrashing and shelling is higher under a 5-year cycle due to the emphasis placed by the farmer on tuber crops at the expense of cereals.

The highest energy output in the form of economic yield per hectare for cereals was obtained under a 30-year cycle; this declined drastically with the shortening of the cycle. However, the energy output through vegetable, tuber, and rhizomatous crops was higher under 5- and 10-year cycles than under a 30-year cycle (Fig. 2).

When one compares *jhum* with valley cultivation of rice, the major input is for land preparation (with an energy expenditure of 55 percent) followed by weeding. Fertilizer is the major input for terrace cultivation, accounting for 82 percent of the total input into the system; clearing vegetation and terrace preparation are chiefly restricted to the first year (Table 7). As maximum input of energy for valley cultivation is for land preparation, it is efficient from the land-use point of view.

Energy output under terrace cultivation, obtained through grain and seed crops, was about one-third of that under a 30-year *jhum* cycle, although energy output through leaf and fruit vegetables, tubers, and rhizomes was higher than that under *jhum* (Table 8). Valley cultivation with two crops annually gave almost the same energy yield as 10- or 30-year cycles.

The labor energy input pattern of male and female workers of *jhum* under a 5-year cycle and terrace and valley cultivation was studied in the high-elevation *jhum* system (Fig. 3).

The findings would essentially hold true for many tribal communities; more than 65 percent of the total work is done by the female members of the family. However, the work done by males and females for the initial slashing of undergrowth is similar. Slashing larger trees, if any, is done by males. While preparation of land into ridges and furrows along with burning and seed sowing is an exclusively female operation, weeding and maintenance of the plot is almost equally shared between male and female members. Transport of harvest and sale is exclusively done by males while other operations such as sowing, weeding, field maintenance, and harvesting are mostly done by females.

The energy distribution pattern over a year (Fig. 4) shows uniform distribution of labor for *jhum* allowing time for other activities such as valley cultivation and for animal husbandry and domestic activities in the village. Terrace cultivation, requires heavy input of labor for land preparation. One of the main advantages of *jhum* is that

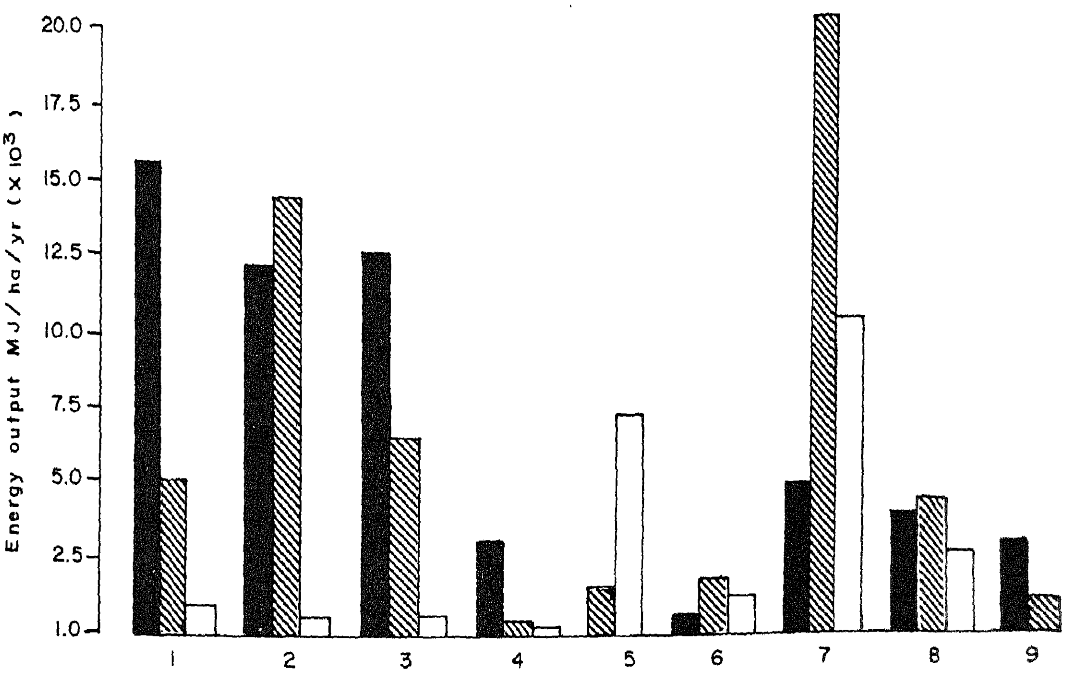


Fig. 2: Comparison of energy outputs from various crops under 30-, 10-, and 5-year *jhum* cycles. Dark column, 30-year cycle. Hatched column, 10-year cycle. Open column, 5-year cycle. 1. *Oryza sativa* 2. *Sesamum indicum* 3. *Zea mays* 4. *Setaria italica* 5. *Musa sapientum* 6. *Hibiscus sabdariffa* 7. *Manihot esculenta* 8. *Colocasia anticuorum* 9. *Cururbits* (after Toky and Ramakrishnan 1982).

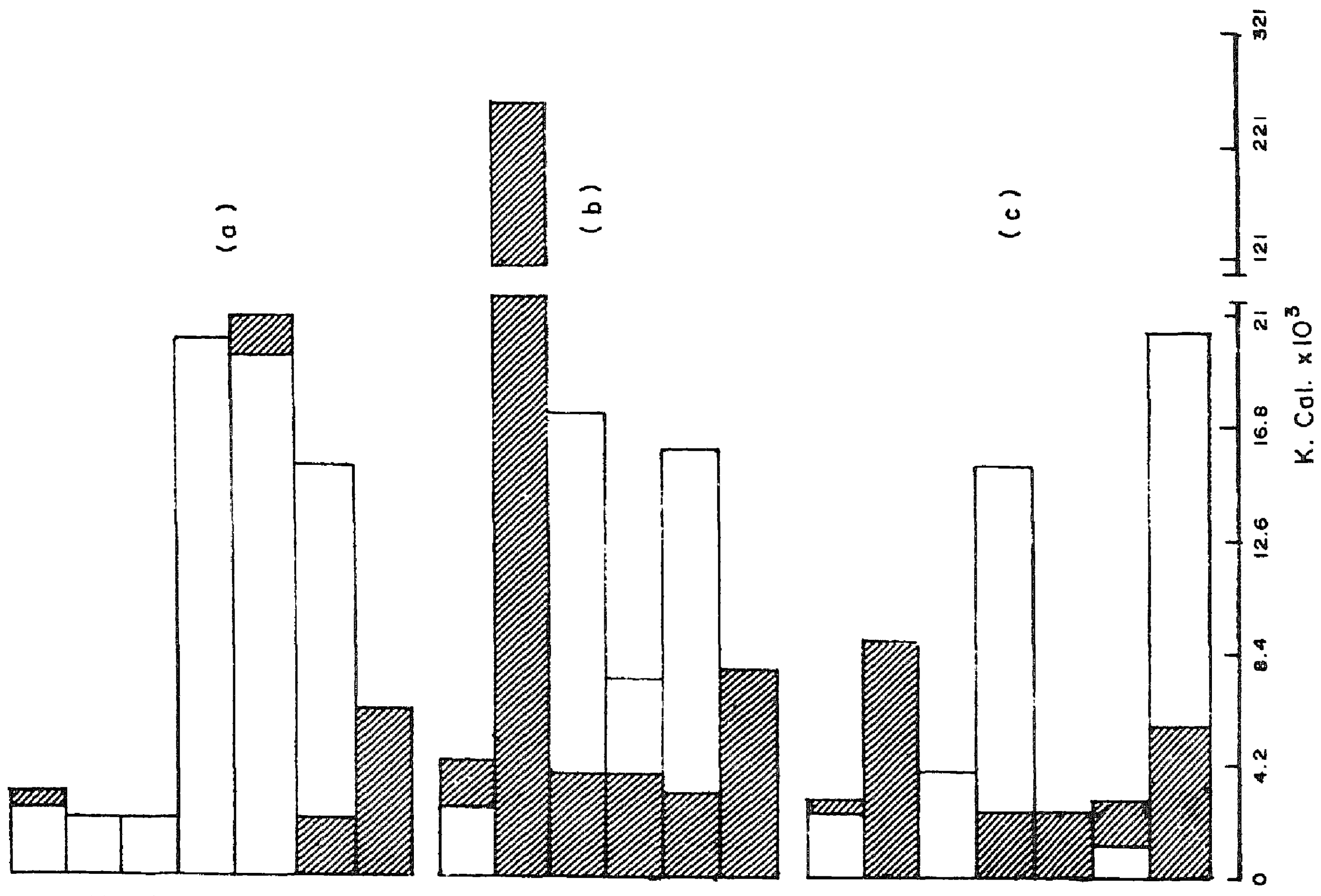
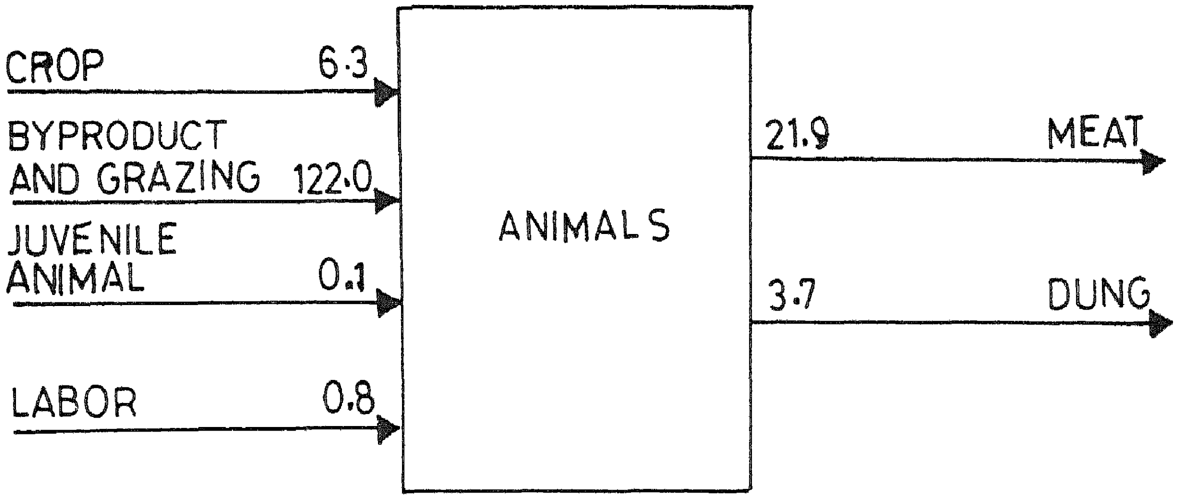


Fig. 3: Allocation pattern of labor between male and female members of the family under different agricultural system (a, 5-year *jhum* cycle; b, terrace cultivation; c, valley cultivation). Hatched column, male labor; open column, female labor. 1. clearing the vegetation 2. land preparation 3. burning 4. seed sowing 5. weeding and field maintenance 6. harvesting 7. transportation 8. threshing and milling (Mishra and Ramakrishnan 1981)



Output : Input ratios

Meat (+ byproduct + grass) = 0.17

Meat (- byproduct + grass) = 3.04

Meat + dung = 0.20

Fig. 4 Energy input-output pattern and efficiency ratios:

Animal husbandry subsystem. Unit = MJ x 10^3 (after Mishra and Ramakrishnan 1982)

Table 7: Energy Input (MJ ha - 1 yr - 1) for Agriculture under Different *Jhum* Cycles and Terrace Cultivation (after Toky and Ramakrishnan 1982)

Agricultural Operation	Energy Input (MJ ha - 1 yr 1)			
	Jhum Cultivation			Terrace Cultivation
	30-yr cycle	10-yr cycle	5-yr cycle	
Labour Input (total)	1615	1148	494	984 (1478)
Clearing under storey Vegetation	274	331	78	293
Felling trees and Bamboos	583	319	-	(595)
Collection of Debris and Burning	51	35	5	(140)
Terrace Preparation	-	-	-	(759)
Dibbling, Broadcasting and Transplantation	40	43	43	41
Hut Construction	23	24	24	
Weeding	63	76	87	44
Guarding the Field from Wild Animals	71	70	64	86
Rearing Caterpillars	123	-	-	110
Harvest	187	198	173	276
Transportation	21	13	8	24
Threshing	77	25	5	41
Shelling	128	42	7	69
Seed Input	24	15	16	202
Fertilizer	-	-	-	5323
Total Energy Input into the System	1665	1181	510	6509 (8003)

Figures in the Parenthesis indicate Values for the First Year of Terrace Cultivation

Table 8: Energy Outputs (MJ ha - 1 year - 1) under Terrace Cultivation (after Toky and Ramakrishnan 1982)

	Crops Species	Energy Output (MJ ha - 1 year - 1)
Grain and seed crops	*Oryza sative*	13024
	Senamum indicum	545
	Zea mays	2347
	Phaseolus mungo	114
	Ricinus communis	208
Leafy and Fruit Vegetables	*Musa sapientum*	2686
	Hibiscus sabdariffa	1245
	Cucurbita mixima	1418
	Momordica charantia	142
	Phaseolus vulgaris	224
Tuber and Rhizome Crops	*Manihot esculenta*	19639
	Colocasia anticuorum	1351
	Zingiber officinalis	330
	Curcuma longs	245
	Cocoon (silk)	80
	Pupae (without cocoon	4

it provides leisure time for the farmer.

The energy output/input ratio was high under all *jhum* cycles. It was much lower under terrace cultivation. Because of higher labor input for land preparation under valley cultivation, the efficiency ratio was lower, although the energy output was closer to 30- and 10-year *jhum* cycles. However, this system is superior to terrace cultivation. The main point of difference in energy input between terrace and other land use systems is qualitative in that the former depends heavily upon fossil fuel energy while all others are labor-intensive. (Table 9)

Energy in Relation to Land Use

The comparative energy efficiency of the *jhum* cycles cannot be considered in isolation but needs to be discussed in relation to land-use patterns. Energy efficiency values per se could lead to a distorted comparison for different *jhum* cycles (e.g. a *jhum* site cropped once in five years as compared to once in every 10 or 30 years). What has been discussed is indicative of the trade-off between land area and energy input. If land is not a limiting factor, then the greater solar energy input to a larger area of the *jhum* system with a longer cycle could be used to offset imported energy and this would ensure harmony of the long cycle with the environment, and at the same time ensure rational returns to the farmer. However, with increase in population pressure and decrease in land area available for *jhum*, due to environmental degradation with permanent weedy communities of arrested succession or even extreme

Table 9: Energy Ratios in Agricultural Systems - *Jhum*, Terrace and Valley Cultivation (after Toky and Ramakrishnan 1982)

Agricultural System	Energy (MJ ha - 1 yr - 1)		
	Input	Output	Output/Input ratio
Jhum 30-yr Cycle	1665	56766	34.1
Jhum 10-yr Cycle	1181	56601	47.9
Jhum 5-yr Cycle	510	23858	46.7
Terrace	6509	43602	6.7
	(8003)		(5.4)
Valley - I and II Crops	2843	50596	17.8

desertification (Ramakrishnan et al 1981), land is in short supply, resulting in very short *jhum* cycles of four to five years. In such a situation, the longer the *jhum* cycle, the larger the land area needed. However, the effective output per hectare would decrease due to a correction factor depending upon the *jhum* cycle. Thus for the 30-, 10-, and 5-year *jhum* cycles at lower elevations of Meghalaya (Toky and Ramakrishnan 1982), the effective output per hectare would decrease due to a correction factor of 1/30, 1/10, or 1/5 so there is an effective output of 1892.2, 5660.1, or 4771.6 MJ per hectare. On this basis, a 10-year *jhum* cycle is the most efficient in terms of energy ratio and land use.

Energy Efficiency of a Semi-Industrial Agricultural System

Terrace cultivation, suggested as an alternative to *jhum*, involves labor for terracing in the first year, along with continued heavy input of fertilizers. This makes it inefficient from energy and economic viewpoints, although the output is only slightly less than that under a 10-year *jhum* cycle when the land re-use pattern is not considered, as evident at lower elevations (Toky and Ramakrishnan 1982)

This system is comparable to more modern Indian agricultural systems, where nine units of food energy are harvested for each unit of fossil fuel energy put into the system (Mitchell 1979), and better than most Western agricultural systems, where the yield is one or two units of food energy per unit of energy input (Spedding 1975; Spedding and Walsingham 1976; Leach 1976; Pimental and Pimental 1979). Apart from energy efficiency, the system is not stable; even if soil erosion is checked to some extent by terracing, infiltration losses would still prove heavy (Ramakrishnan et al 1981a; Toky and Ramakrishnan 1981b).

Furthermore, heavy input of fertilizer in such a high-rainfall region may result in serious environmental problems. In the ultimate analysis, this form of land use has not found much favor with local populations. In fact, the life of the terraces themselves often is not more than six to eight years.

General Considerations

If one considers that the 4 to 5-year *jhum* cycle now prevalent in the northeastern hill region is untenable from the point of view of energy and land use, and if it is further realized that terracing is neither ecologically nor economically viable as an alternative to *jhum*, the only alternatives seem to be to have cereal cultivation under a 10-year *jhum* cycle (which is not feasible under present conditions of pressure on land) or to confine cereal cultivation to valleys, which does not demand any fertilizer input and permits a dependable good return on a sustainable basis and also has fairly high energy efficiency. The main limitation of valley cultivation, however, is that imposed on it due to topography. Hence, this system of land use may have to be supplemented by a minimum cycle period of 10 years for *jhum*, assuming that *jhum* has to be retained as a land-use practice. It is in this context that alternative land-use strategies become important, with cereal cultivation confined to valleys or restricted under 10-year *jhum* cycles. It may be profitable to consider horticultural and plantation crops on hill slopes as a limited alternative to controlled *jhum* with a 10-year cycle, since these have been a success on an experimental scale in this region.

In the wider context of Indian agriculture, it should be possible to replace use of imported chemical fertilizers by local resources based on bio-fertilizers using available manpower most effectively (for example, small-scale irrigation projects) for stability of agricultural production. With the large majority of rural households composed of small and marginal farmers, more emphasis on agricultural technology based on local natural resources, rather than a total shift to that chiefly based on chemical fertilizers, seems to be appropriate.

ENERGY BUDGET AND VILLAGE ECOSYSTEM FUNCTION UNDER *JHUM*

The industrialized societies of today face reduced flexibility owing to their strong dependence on petroleum and other fossil fuel-based products, becoming scarce and costly. The way many societies have evolved in the past, in harmony with low levels of energy supply, may provide clues as to how modern societies could adapt to the limitations imposed by energy scarcity. In a study of a typical Khasi village ecosystem under *jhum* at higher elevations of Meghalaya, the relationship between food and energy, inputs into the food production system, energy flow through primary and secondary food production units, energy needs for cooking and the manner in which they are met, and cost-benefit analysis of village functions are examined (Mishra and Ramakrishnan 1982). Such analyses of energy flow patterns through various compartments of a society adapted to low-energy inputs are few (Rappaport 1971; Odum 1971; Leach 1976).

In the village ecosystem at Sethliew in northeast India, *jhum* and valley cultivation are the two major land uses, apart from fallow land under natural vegetation. Closely associated with the *jhum* agricultural system is swine husbandry. Animal husbandry systems are closely interlinked with shifting agriculture in traditional societies the world over.

While this animal husbandry practice may not be efficient elsewhere, as with the Tsembaga farmers in the New Guinea highlands (Rappaport 1971) who raise a single a pig over a 10-year period with only 1.5 percent return on the food energy as pig meat energy (Pimental and Pimental 1979), the practice in India is more efficient (Fig. 5). The demands on the Khasi farmer are lighter and the animals feed chiefly on vegetable waste as they browse and on cheap feeds such as poor quality tubers unfit for human consumption. The cost of rearing is further lowered for Khasi farmers as their pigs are slaughtered every year rather than once in 10 years as under the Tsembaga system.

At Sethliew, the domestic subsystem has low energy efficiency (Fig. 6) with food and fuel for cooking being two inputs into this subsystem, which generates manpower used for agriculture and animal husbandry. Fuel for cooking is an important need of the domestic subsystem, more than half of which is imported from outside the village ecosystem. One of the consequences of shortening the *jhum* cycle (Ramakrishnan et al 1981a) has been rapid depletion of the fuelwood resources of the region. This is aggravated due to low-efficiency fuelwood energy utilization in the developing world (Leach 1976) where the per capita consumption of energy for cooking is considered to be over two and a half times more than in the West. (Table 10)

Table 10: Annual Fuel Consumption for Cooking in the Village Ecosystem (after Mishra and Ramakrishnan 1982)

Category	Quantity kg	Energy Equivalent (MJ)
Firewood	5033	86276
Rice husk	328	6032
Total		92308 (92033)

Value in Parenthesis is the standard requirement.

In the Sethliew village ecosystem, about 70 percent of the protein yield is of plant origin and the rest is of animal origin. Rice, the staple diet of the people, along with maize, accounted for over 70 percent of the total food energy and about 67 percent of the protein consumed by humans. Pork, the only form of meat consumed, accounted for about 13 percent of the food energy (Table 11).

Results suggest that the high energy efficiency and energy balance of the village ecosystem as exemplified at Sethiew are adversely affected in villages under shorter *jhum* cycles and in areas where there is degraded land under arrested weed stage of succession (Saxena and Ramakrishnan 1984) or in desertified sites as at West Khasi Hills District in Meghalaya. The self-sufficiency of the village ecosystem

Table 11: Annual Food and Protein Consumption in the Village Ecosystem (after Mishra and Ramakrishnan 1982)

Category	Food Quantity (kg)	Energy Equivalent (MJ)	Protein Equivalent (kg)
Solanum tuberosum	88.96	1288	4.16
Colocasia antiquorum	43.30	629	4.23
Ipomoea batatus	360.00	5965	15.59
Zea mays	342.80	5685	44.02
Oryza sative	2567.00	42538	213.57
Phaseolus vulgaris	10.78	169	2.55
Cucurbitus maxima	28.00	430	6.00
Pork	112.50	8560	93.49
Total		65264 (67383)	383.61 (321.20)

Values in Parentheses are the Standard Requirements

also is adversely affected.

These studies also show that the village ecosystem function in the northeastern hills varies in relation to ecological conditions and social and cultural factors. A variety of lesser-known plants of food value are used by the different tribes. These are either cultivated in their *jhum* plots or collected wild.

These food plants supplement carbohydrates and proteins obtained through conventional crops. Apart from a variety of leafy ferns used in the Mokochung District in Nagaland, the Naga tribes use two weedy species: *Ghetum montanum* and *G. gnemon*. The Khasis in Meghalaya cultivate at least two important lesser known crop species in their *jhum* plots, namely *Pesilla ocimoides* and *Flemingia vestita*. When one realizes that by the turn of the century, conventional food resources may have to be supplemented by new sources to feed the increasing world population of which a large proportion would be in the underdeveloped world of the tropics, this ethnobiological study becomes urgent.

ENERGY, ENVIRONMENT, AND DEVELOPMENT

Self-sufficiency in food is the chief concern of any developing society. A variety of strategies to make *jhum* viable in terms of food yield could be designed. While longer *jhum* cycles of

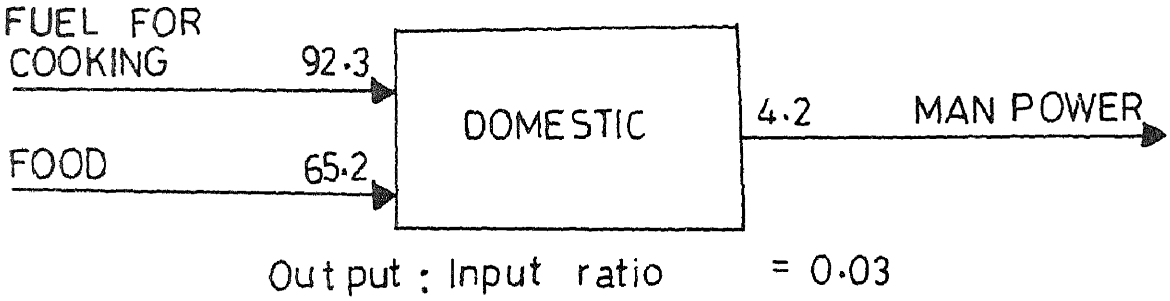


Fig. 5: Energy input-output pattern and efficiency ratios: Domestic subsystem. Unit= MJ x 10 (Mishra and and Ramakrishnan 1982)

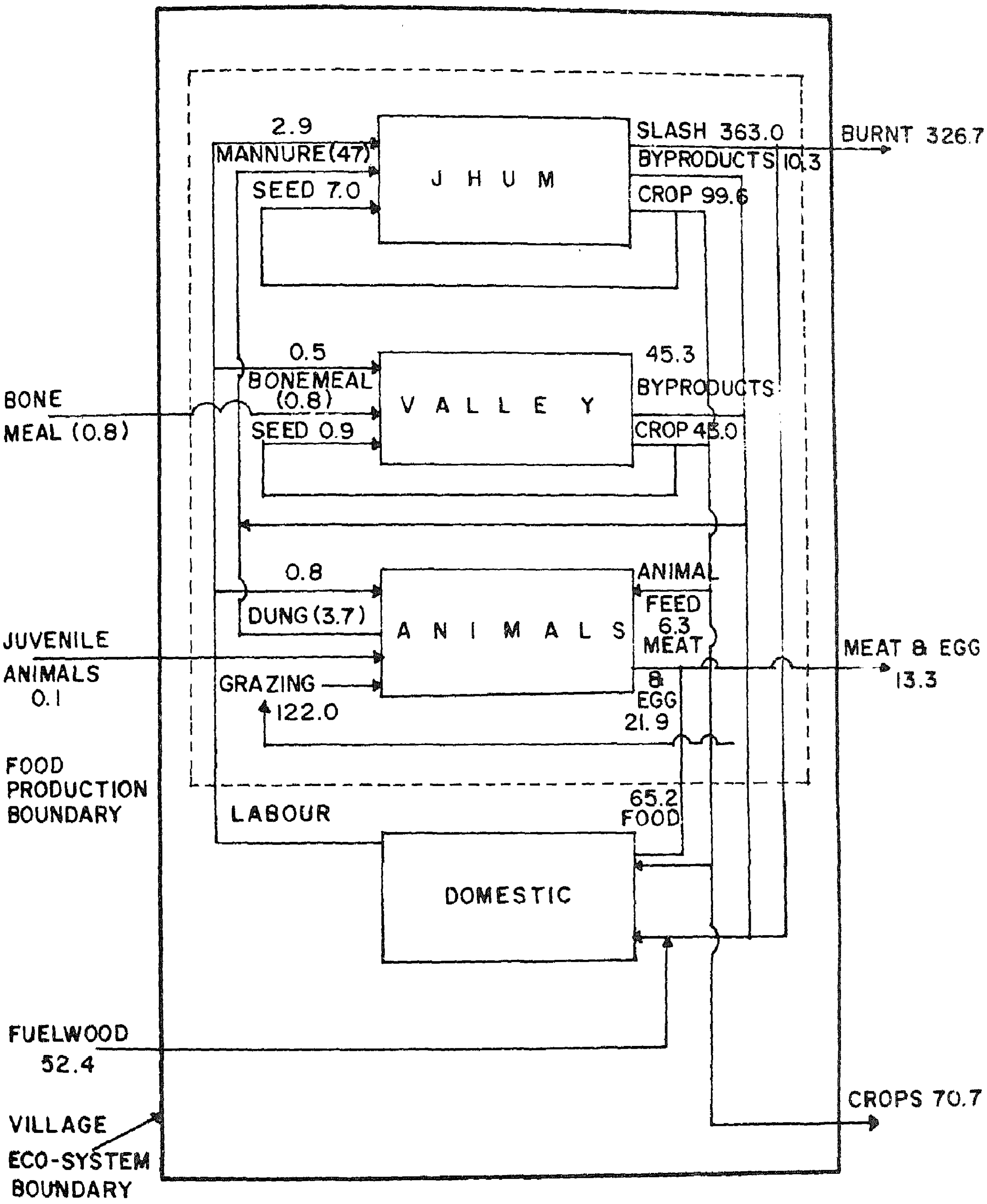


Fig. 6: Energy flow model for the village ecosystem at Sethliew.

Values within parentheses refer to the replacement cost in terms of fossil fuel. Unit = MJ x 10 3 (Mishra and Ramakrishnan 1982).

10 years or more are both ecologically and economically viable, one way of taking the pressure off the land is to diversify economic activities. Encoraging horticulture/plantation crops, intensifying valley cultivation through modern inputs, and improving animal husbandry are some possibilities. Even with the current short 5-year cycle, introduction of identified legumes and non-leguminous trees and shubs during the fallow phase could ensure reasonable recovery of the soil fertility depleted during the cropping phase, making such a cycle more productive. A tree line around *jhum* plots would also check nutrient losses that occur through wind and hydrology during the cropping phase itself (Toky and Ramakrishnan 1981b; Mishra and Ramakrishnan 1983a). Apart from improving the *jhum* system itself, a tree line would provide fuelwood energy, a major fraction of which has often to be imported from outside the village at present. An examination of the native species with fast growth rates that could be exploited for such a social forestry program has been undertaken (Ramakrishnan et al 1982). The introduction of identified native trees during the fallow phase as part of the social forestry system for the tribal communities could contribute to their energy needs (Ramakrishnan 1984b 1985a,b). Such an acceleration of the fallow phase regrowth of secondary successional plant communities (Toky and Ramakrishnan 1983a; Mishra and Ramakrishnan 1983c) would help speed fertility recovery processes (Ramakrishnan and Toky, 1981; Toky and Ramakrishnan 1983b; Mishra and Ramakrishnan 1983b,d). Energy-efficient stoves for cooking would further contribute to the village ecosystem function from an energy viewpoint.

Agroforestry systems with fast-growing native tree species, along with a variety of crops, could meet the food, fodder, and fuelwood needs of the people. Cash crops with horticulture/plantation crops either as part of the agroforestry system or apart from it, could encourage an export-oriented economy which should be secondary only to self-sufficiency of the village ecosystem in hill areas. Improvements on valley land agro-ecosystems through better crop varieties and management techniques could increase cereal production and considerably augment the *jhum* system. Improved animal husbandry practices are other possibilities for supplementing food energy and meeting protein needs. High technology of low magnitude for semi-processing of the produce of rural areas is possible. Semi-processing of tea, coffee, or rubber could be organized for a cluster of villages before transport to city centers for final processing.

Nowhere is the interlinkage between energy and environment so evident as in the tribal societies of the northeast (Ramakrishnan 1985a). The distortions brought about in tribal societal functions due to deforestation could be corrected through revegetation strategy using native species (Boojh and Ramakrishnan 1982a, b, c, 1983; Ramakrishnan and Shukla 1982; Ramakrishnan et al 1982; Shukla and Ramakrishnan 1984a, b, 1986; Ramakrishnan 1985b).

Public intervention for development should be first to design development packages suited to a given ecological zone after these are identified. These packages should be implemented with people's participation, by taking advantage of the cooperative spirit ingrained into traditional societies. Apart from providing acceptable technology that is in accord with the value system of the tribals, the government agencies can act as catalysts for providing the organizational base both for production and marketing.

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APPENDIX - 1

Energy Calculations

Solar energy, which is the primary source of energy, and the slash burnt during shifting cultivation, do not enter into calculations for energy efficiency of this agro-ecosystem as these are considered to be 'free' inputs and no special effort goes into obtaining them. The input of energy through seeds was calculated on the basis of the total energy expended to produce that fraction of the crop yield. Total food energy consumed was apportioned to each activity (Leach, 1976)[1] according to relative duration on the basis of grouping involving either sedentary, moderate or heavy work. Per hour energy expenditures of 0.418 MJ for sedentary work, 0.488 MJ for moderate work and 0.679 MJ for heavy work for an adult man and 0.331 MJ for sedentary work, 0.383 MJ for moderate work and 0.523 MJ for heavy work for an adult woman were used to calculate the labour energy 2 input into the system (Gopalan et.al. 1978). The energy values for economic yield of crops were estimated after burning the samples in a bomb calorimeter. Energy input through organic manure was calculated on the basis of their replacement cost (pig dung, 1.32; goat dung, 2.0; fowl dung, 4.78; dung + vegetable manure, 1.46; bone meal, 5.87 MJ Kg_{-1})

For the estimation of the annual meat production, the weight gained by each category of animal at the time of slaughter was calculated and the values thus obtained were connected using a dressing percentage (Ranjhan, 1977) 3 of 75, 56 and 70 for pig, lamb and fowl respectively. Using the energy values of 4. 937, 4.560 and 7,238 MJ Kg^{-1} for goat meat, chicken and eggs, respectively (Gopalan et. al, 1978)and 17.121 MJ Kg^{-1} for pork (Ranjhan, 1977) the energy equivalent of secondary production through animal husbandry was calculated. The estimation of the feed/fodder consumed by livestock was based on the daily rations given to the animal and their energy values. For calculation of browsing by the animals it was assumed that the energy equivalent for this would be equal to the value obtained after subtracting the energy value of the actual feed consumed from their standard food energy requirement (Ranjhan, 1977).

The fuelwood energy calculations for the domestic sub-system were based on the value of 17.142 MJ Kg^{-1} for slash, calculated using a bomb colorimeter. Estimation of the actual amount of food/fuel consumed by humans was based on actual observations, and the energy equivalents.

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1. Leach, 1976 (as in references)

2. Gopalan, C.B. , Ramasastri, V. and Balasubramanim v. 1978. Nutritive value of Indian foods. Natl. Inst. Nutrition, Hyderabad and the input through inorganic fertilizer is based on production cost (N, 76.99; P_2O_5, 13.95; K_2O, 9.67 MJ kg^{-1})

3. Ranjham, S.K. 1977.Animal Nutrition and feeding practies in India.Vikas Pub. House Pvt. Ltd., New Delhi.
of all the items consumed were calculated using their respective energy values. For calculatingthe theoretical food energy requirement of humans, the energy consumption scale suggested by Gopalan et al (1978): (one adult male, 1 unit; one adult female, 0.9 unit; children aged 5-7 years, 7-9 years and 9-12 years, 0.6, 0.7 and 0.8 units respectively), was used for conversions into units. This was then multiplied by the food energy equivalent of an adult (one unit) of 10.042 MJ day 1 (Gopalan et al, 1978). The values of food energy thus obtained (nutritive values) were then corrected to the heat of combustion by multiplying with the coefficient of 1.149 (Mitchell, 1979). To find the energy equivalent of fuelwood needed per day for cooking purposes it was assumed that the potential energy required for one adult man (one unit) would be 15.759 MJ (Mitchell, 1979).

4. Mitchell, 1979 (as in references)

Section 4 : ENERGY PLANNING

ENERGY DEMAND AND SUPPLY IN THE INDIAN HIMALAYA

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INTRODUCTION

Energy consumption is closely related with level of economic activities and standard of living. Peculiarities of the Himalaya region keep the use of energy in favor of noncommercial sources in this area. Pressure on these sources due to increased population and economic activities has been beyond the supporting capacity for a considerable period of time. The resulting ecological damage is a matter of concern due to its wide ranging repercussions in several spheres, including quality of life of the people in rural areas.

The Indian Himalaya has unique features like small and sparsely populated villages, high energy requirements due to climatic and topographical conditions, dependence on firewood as the main source of domestic energy, and lack of proper infrastructure, which in turn affect demand patterns and supply sources of energy. This paper attempts to provide relevant information, and is expected to be helpful in formulating an appropriate strategy to balance energy demand and supply in this region.

ENERGY DEMAND

Consumption Pattern: Survey of Micro and Macrostudies

Microstudies that have been reviewed cover mainly rural areas where noncommercial sources of energy are predominantly used. Most of the microstudies do not cover all sources of energy and all energy-consuming activities of the areas surveyed, yet they bring out the typical patterns of energy consumption in the Himalaya region.

Satsangi and Gautam (1983 a, b) covered four village clusters of Nainital District and one village cluster of Agra District on the plains of Uttar Pradesh (U.P.) and studied energy use in various rural activities. The study also brings out the difference in the energy consumption pattern in Nainital within the subregions of the hills, *bhabhar* and *Tarai*.

Noncommercial was the main energy source in Nainital village clusters, contributing 95 percent in some areas. Firewood was the single most important, with 99 percent share in total energy use in the hill cluster compared to 36 percent in the plains cluster of villages. The variation in consumption of firewood between summer and winter was pronounced in the case of the hill cluster, where average winter consumption was more than double that of summer consumption. Also, space and water heating consumed a higher percentage (29 percent) in the hill region compared to the Tarai (6 percent) and still lower in the plains.

Animate energy use was higher in the hill region (98 percent) compared to the Tarai (13 percent), indicating mechanization and pump irrigation in the plains. Industry, transport, and commerce sectors did not display any pattern, and energy consumption was dependent on type of industries, trade, mode of transport, and location of village cluster. Mix of commercial and noncommercial in these sectors was also dependent on these factors.

The next two studies are benchmark surveys of villages chosen to test suitability for a biogas program. The village of Jagaria in Kangra District of Himachal Pradesh (Agrawal 1980a) had comparatively good economic conditions. Firewood was the only source of fuel in the village for cooking and water/space heating. Dharmuchack village (Agrawal 1980b) had its households mostly from backward classes and poor economic strata. Dung was used both as fuel and fertilizer, but firewood was the main source of domestic energy.

The study by Sagar et al (Pilot Survey of Fuel Consumption in Rural Areas 1981) indicates increased use of dung as fuel moving from the hills towards the plains. In the village of Chakrata (Dehra Dun District) only wood was used as fuel whereas in Harrawala (towards the plains of Dehra Dun District), dung was also used as fuel.

Marcus Moench (1985) selected the village of Munglori in Tehri Garhwal District of U.P. for the study of biomass utilization patterns. The village selected was such that outside pressures (like commercial) were absent and the village had abundant biomass resources. Only wood and twigs were used as fuel in the village. Decline in quality and availability of forest resources over a period of time resulted in increased collection time for fuel and fodder.

The National Sample Survey (NSS) conducted a household fuel and light consumption survey, in its 18th (1963-64) and 28th (1973-74) rounds. Results from the 18th round for hill states covered in the survey (J & K, H.P., Manipur, Tripura) have been averaged on a weighted basis and presented in Table 2. The results of the 28th round are not significantly different from the 18th round.

It was observed that consumption of firewood in all hill states was more than double the all-India average. Average dungcake, electricity and kerosene use was comparatively less in hill states. Overall average per capita household energy consumption in hill areas was approximately 1.7 times that of the all-India average.

The rural northern India survey of 1975-76 by the National Council of Applied Economic Research (NCAER 1981) sampled 100 villages of rural northern India. The estimated population of hill areas covered in the study was 15.7 million. Its coverage of energy-using activities and energy sources is comprehensive. It also gives results for hills, plains, and deserts separately. Data has been collected for summer and winter both. To allocate collected fuel, it used correlation between fuel consumption per unit of foodgrains consumed and income level.

Annual household energy consumption in hills was highest (1656 kg Coal Replacement CR) which was 30 percent more than plains. Firewood accounted for 67 percent, agricultural residue 21 percent and dungcake 5 percent, with the balance being commercial sources. Noncommercial fuels were mostly collected and mainly used for cooking (88percent) and heating. Water and space heating consumed a higher percentage of energy in the hills (9.5 percent compared to 4.3 percent in the plains).

Average energy input in agriculture including fertilizer was 1788 x 10 kcal/ha in hill areas, 22 percent less than the plains. However, animate energy percentage was higher in hill areas (93 percent compared to 82 percent in plains). For establishments, separate data for hill areas is not available and hence, is taken as the same as average for the northern region. The per capita consumption of various fuels in different activities is indicated in Table 1.

Energy was also spent in obtaining drinking water, and the percentage of households using an outside water source was high in hill areas (60 percent compared to an average of 40 percent for the northern region). Overall per capita annual consumption for all sectors from all types of energy sources was 220.6 x 10 kcal, of which 74.8 percent was noncommercial, 5.4 percent commercial, 18.7 percent animate, and the balace about 1 percent fertilizer. Domestic energy constituted 90 percent of overall per capita consumption, excluding animate and fertilizer. Its share in total commercial and noncommercial was 24 percent and 95 percent respectively.

NCAER 1978-79 all-India domestic energy consumption survey (NCAER 1985) gives data by state. It covered energy consumption in commercial establishments, households, and rural industries. The weighted average per capita energy consumption has been calculated for the hill region and indicated in Table 2. Per capita annual energy consumption (excluding establishments) for the hill region was 257 kg Coal Replacement, which was 25 percent more than for the plains. The consumption of logs as a percentage of total firewood was 48 percent for the hill region compared to 3 percent (all-India average), and the highest was 75 percent in Meghalaya.

The fuel consumption data from various studies has been summarized and presented in Table 2. The variation in pattern is brought out by microstudies, for example, variation in annual firewood consumption from 231 kg to 2167 kg per capita, and dungcake from nil to 370 kg per capita. Differences in methodologies used for data collection do not permit exact comparison of macrostudies.

Demand Projections

Energy consumption estimates for hill areas from NCAER's latest study (1985) have been taken as the base for projections of domestic energy requirements. However for total energy demand projection, the share of other sectors is taken from the NCAER study (1981), which covered these sectors also. The assumptions are:

- Population growth rate is the same as in the past (30 percent in approximately 19 years).

- Per capita energy consumption will

Table 1: Per Capita Annual EnergyConsumption in Rural Hill Areas

Source	Unit	Household	Agriculture	Establishment	Construction	TPT	All Sectors
Commercial							
Coal/Coke	Kg	0.50	-	4.45	-	0.77	5.8 (10 %)
Electricity	KWH	3.71	1.26	1.40	-	0.05	6.42 (5.8%)
Kerosene	Litre	2.63	-	0.89	-	-	3.52 (75 %)
Diesel	Litre	-	0.32	0.27	-	1.27	5.38 (-)
Petrol	Litre	-	-	-	-	0.14	0.14 (-)
Furnace Oil	Litre	-	-	0.02	-	-	0.02 (-)
Non-commercial							
Firewood	Kg.	239.12	-	5.72	-	-	244.84 (98 %0
Dungcake	Kg.	47.98	-	5.17	-	-	53.15 (90 %)
Veg. Waste/ agr. Residues	Kg.	84.57	-	10.89	-	-	95.46 (89 %)
Charcoal	Kg.	3.95	-	1.10	-	-	5.05 (78 %)
Animate Manpower	Mandays	-	47.47	9.17	0.67	0.90	58.21 (-)
Draught Power	Ani. Days	-	15.14	-	-	1.00	16.14 (-)
Nitrogen	Kg.	-	9.27	-	-	-	(-)

Source: Compiled from NCAER Survey (NCAER - 1981) Figures in Bracket show percentage of Domestic Energy.

1. For establishments, energy consumptions has been determined by NCAER based on employment data
2. Not calculated
3. This is not representative of the hill region since most transport is by animate and diesel/petrol (It represents rail traction)

Table 2: Per Capita Annual Domestic Energy Consumption in Hill States (Summary of Studies[1])

FUEL	Micro Studies Satsangi-1983 (Nainital Dist.)	Agrawal-1980a (Jagaria-HP)	Agrawal-1980b Dharmuchack- (Garhwal)	Sagar-1981 Chak- rate	 Harra- wala	 Kana undi	Moench-1985 Munglori (Garhwal)
Coal/Coke kg.	-	-	-		-	-	-
Kerosene Litre	-	8.76	7.68	-	-	-	-
Electricity kwh	-	-	-	-	-	-	-
L P G	-	-	-	-	-	-	-
Fire kg.	231 to 897[2] (Wt. Av. = 371)	2167	462	1116	504	224	970
Charcoal kg.	-	-	-	-	-	-	-
Agri Res. kg.	-	-	-	-	-	234	-
Dung Cake kg.	0 to 370[2]	-	86	-	64	130	-

1. Figures are left blank (---) wherever calculation from given data in study was not possible, and where data value is nil/is not at all calculated in study (-).
2. kgCR values given in Study were converted assuming use of open chullah and hence 1 kg wood = 0.70 kgCR.

Table 2 (Contd.)

FUEL	Macro studies (Data for hill region only) NSS - 18th Round	 NCAER - 1981 (only rural region)	 NCAER - 1985
Coal/Coke kg	1.44	0.58	1.23
Kerosene Litre	5.04	2.63	6.05
Electricity KWH	1.92	3.71	15.36
LPG kg	-	-	0.37
Firewood kg	513	239.12	294.43
Charcoal kg	1.92	3.95	4.67
Agri. Residues kg	(included in firewood)	84.57	11.59
Dung cake kg	61.68	47.98	70.07

remain unchanged until 1991 and increase by 10 percent by 2001 A.D.

- Share of other sectors (industries and establishments, agriculture, and transport) will increase from 8 percent in 1975-76 to 15 percent by 1991 and to 25 percent by 2001 A.D. Share of commercial energy increases from 46 percent to 60 percent and to 90 percent respectively during the same period, in sectors other than domestic. Pattern of fuel mix in the domestic sector is taken to be constant.

- Efficiency of fuel use is taken as constant at the 1978-79 level. The energy demand projections have been worked out for 1991 and 2001 A.D. and presented in Table 3.

It is imperative to mention that:

1. The share of other sectors in total energy taken as 8 percent in 1975-76 is for rural areas only. Since the share is expected to be more in urban areas, total energy requirements will increase accordingly.
2. The per capita consumption taken in 2001 A.D. is equivalent to 447 kcal per capita per day of household energy, whereas the Advisory Board on Energy (ABE 1985) has the fixed target of 680 kcal; to achieve this, quantities of fuels required will increase by 50 percent.

It can be seen from the table that a huge increase in energy is required over the 1980-81 consumption level. The total fuel requirements increase by 41 percent in 1991 and by 128 percent 2001, with a mere 10 percent increase in per capita consumption in 2001. To meet the standard envisaged by ABE, the increase required is 195 percent in 2001, implying three times the present level of energy consumption. In case extra energy requirements of the hill region to maintain the same standard of living as the plains are considered, the estimates shall further increase by at least 20 percent. This is to cater to long winters, low ambient temperatures, and pressure in hill areas.

SUPPLY OF ENERGY

This section investigates the various energy supply sources, their potentials, and associated problems.

Firewood

The forested area in the country as revealed by satellite imagery results (Paryavaran 1984) is about 14 percent of the geographical area, against the official record of 23 percent. The satellite imagery indicates 15.2 million ha of forest area in the hill region. This is 29 percent of the geographical area against the recommended 60 percent by the National Forest Policy Resolution of 1952. The estimates of firewood yield from forests vary widely from 0.5 tons/ha to 4-5 tons/ha for conventional firewood forests. For fast-growing trees, it is estimated as high as 6 to 50 tons/ha .(Bhatt 1983). If we assume annual yields of 3 tons/ha and 50 percent of forest area as exploitable, approximately 22 million tons of firewood availability can be expected. Plantation on barren lands, degraded forests, and farmland can give another 42 million tons of firewood

Table 3: **Energy Demand Projections for 1981 and 2001 AD**

Fuel	Unit except for per capita	Reference per capita domestic consumption (1978-79)	Domestic energy required qty.	CR (000) tons	Other sectors requirement CR (000) tons	Total energy required CR (000 tons)
Coal/Coke	000 tons	1.23 kg	43	54	1078	2223
Kerosene	000 K. L.	6.05 lit.	213	579		
Elect.	Mil. kwh	15.36 kwh	542	379		
LPG	00 tons	0.37 kg	13	133		
Total Comm.	CR 000 tons	-		1145	1878	2223
Firewood	000 tons	294.4 kg	10387	7790	720	9764
Charcoal	000 tons	4.67 kg	165	299		
Agri. Residues	000 tons	11.59 kg	409	213		
Dung Cake	000 tons	70.07 kg	2472	742		
Total Non Comm.	CR 000 tons	-		9044	720	9764
Total all fuels	CR 000 tons	-		10189	1798	11987

Table 3: (Contd.)

Fuel	New per capita requirement (Domestic)	Domestic energy required		Other sectors requirement CR (000 tons)	Total energy required CR (000 tons)
		Qty	CR (000 tons)		
Coal/Coke					
Kerosene	1.35 kg	62	78		
Elect.	6.66 lit	305	830	4373	6019
LPG	16.90 kwh	775	543		
	0.41 kg	19	195		
Total Comm.		-	1646	4373	6019
Firewood	323.8 kg	14852	11139		
Charcoal	5,14 kg	236	427	486	
Agri. Residues	12.75 kg	585	304		
Dung Cake	17.08 kg	3535	1061		
Total Non Comm.	-		12931	486	13417
Total all fuels	-		14577	4859	19436

NOTE: The consumption estimates vary in different surveys, especially of NC fuels. Therefore the calculation of per capita consumption up to two decimal places is not indicative of accuracy of estimates, but merely retained for correspondence with aggregate figures.

from the hill region (geographical as 6 percent of the country) based on Firewood Study Committee estimates of 242 million tons for all of India. Based on NCAER (1981) indications of 6.5 million ha fallow land for the northern region, 24 million tons (yield 8 tons/ha) to 45 million tons (yield 15 tons/ha) firewood can be made available, considering 3 million tons of this land is in the Himalaya region.

Raising plantations, however, costs money; the NCAER (1981) estimate is Rs. 25 per ton in 1975-76. Yet another problem is distribution of wood grown on such land. Village woodlots suggested by Makhijani (1977) may not be feasible for several areas due to nonavailability of such land within a reasonable distance. Lastly, there is likelihood of this wood being diverted for commercial purposes.

Dung

The livestock population of the Himalaya region was approximately 17 million in the 1977 census and has increased only marginally thereafter. Approximately 70 percent of these are cattle with dung yield of 8-10 kg per animal. The estimates for dung yield and collection efficiency vary widely. Assuming 40 to 60 percent collection efficiency, availability of wet dung could be between 16 and 29 million tons, which is equivalent to 3.2 to 5.8 million tons of dry dung. To increase this, cattle need to be kept penned, and this in turn would require adequate fodder arrangements.

Agricultural Residue/Vegetable Waste

There are varying estimates for available residue from crops. Roger Revelle (1976) and Makhijani (1977) have taken the residues to foodgrain production ratio as 2:1, whereas the NCAER (1985) study implies it to be 1.14 percent. The available residue in the Indian Himalaya in 1985 is expected to be 6 to 8 tons (with a ratio of 1.5:1). The residue has multiple uses as fodder, fertilizer, and fuel. Increased agricultural production need not necessarily increase residue as high-yielding dwarf varieties produce less straw. The priority use for residue is fodder, and increased fodder availability can increase dung yield also.

Biogas

Only 1 percent of dung is presently in use in biogas plants (Satish Chandran 1985) and the percentage is still lower in the Himalaya region. If about 25 million tons of dung are available (from indicated range) it can yield 1000 million m^3 of gas (and 2.3 times this in summer), sufficient for 1.3 million households of five needing 2 m^2 of gas per day. However, each household needs to have five or six cattle to get the required gas output from a family-size plant. The estimated number of such households is 15 percent (NCAER 1981), but in the case of some hill states like Himachal Pradesh it is as high as 30 percent (NSS 30th round). Community biogas plants can be installed wherever feasible.

Biogas technology offers several benefits like fertilizer (sludge) in addition to clean and convenient cooking fuel, improved environment, related health benefits, income-generating activities during construction of the plant, and possibility of use of biomass and human excreta, which at present do not find alternate uses. However, compared to the present almost 'zero private cost' of fuels in rural areas, it is costly. Present cost is expected to be more than Rs. 5000 for a family-size plant. Further, studies in the past have indicated biogas as uneconomic on social cost-benefit criterion (Bhatia 1977). Even community gas plants have been considered beyond the reach of a common village household due to high cost (Makhijani 1977), and undesirable from accessibility and affordability criteria in addition to sociological and organizational problems (Ranganathan 1983). However, with increasing fuel problems and changing situations this needs a fresh look. Other problems like reduction of gas output at low ambient temperatures, leakage, liquidity of sludge, high water requirements, large space requirements, maintenance of correct pH ratio and distribution of gas have yet to be resolved satisfactorily. Bhatia (1977) pointed out yet another undesirable social consequence of the biogas program: a vulnerable section of society might get deprived of fuel, as dung will not be available for collection.

Electricity

More than 50 percent of hydroelectric potential is in hill regions (including Assam) and less than 15 percent of this has been exploited. The installed capacity in the Indian Himalaya (excluding U.P., W.B. and parts of H.P. in Bhakra) was merely 2 percent and power generated, 1 percent of the total in the country in 1983-84 (based on compilation from CMIE 1984). Per capita annual consumption of electricity in this region varied from 13 kWh in Manipur (lowest in India) to 106 kWh in J and K against the all-India average of 146 kWh in 1982-83.

The projected electrical energy requirement by CEA for this region (excluding U.P. and W.B.) for 1990-91 is 6996 kWh with a peak load of 1397 MW (CEA, 1982). More than 14,500 MW of hydel capacity was under various stages of consideration and execution in the Indian Himalaya from July 1982 onwards (CMIE 1982). Mini and microhydel schemes are of special interest owing to their tremendous potential in this region and suitability for decentralized operation. The Rural Electric Corporation has identified several rural linked mini and microhydel schemes for this region.

Electricity generation might be abundant, but due to high costs of connection and appliances, it is beyond the reach of the majority of households. Even if these costs are subsidized, it is difficult for electricity to replace fuels used for cooking: the major energy-consuming activity of households. Its role is expected to be limited to use in pump irrigation and lighting. Reliability of supply has been yet another problem with electricity, calling for back-up arrangements. Mini and micro hydel may be preferable on this count, as well as the high cost of grid electrification in remote areas.

Coal and Coke

The Indian Himalaya does not have coal reserves except for a small amount of tertiary coal in the northeastern region. Use of coal for cooking has been advocated by Bhatia (1977) based on a social cost-benefit study. However, it will also need subsidy when compared with 'zero private cost' of fuels used for cooking, especially by poor classes. The distribution costs of coal are expected to be higher in hill areas due to long distance road transport and sparse population. The policy being increased use of coal and renewables, the cost of coal needs to be compared with other alternatives.

Petroleum Products

The Himalayan foothills have a small amount of oil reserves and Tripura and Nagaland have some natural gas reserves. However, policy regarding consumption of petroleum products has to be within the broad national policy framework. LPG can contribute in cities to meet cooking energy needs of households with relatively better economic conditions. High appliance and distribution costs do not favor its use in rural areas. The role of kerosene can be seen as supplementing electricity to meet lighting needs. Petroleum products have to mainly meet fertilizer and transport sector requirements.

Nonconventional Energy Sources

Solar Energy. Solar energy technology has been developed for several end uses like water and space heating, cooling, water pumping, and cooking. It is a clean fuel and potential is virtually unlimited with solar radiation intensity of 600 Watts/M^2 and above falling in India. However, the cost of most of the appliances is beyond the reach of the poor classes. Thus, the solar water heater has been found to be economically unviable for large-scale adoption at present level of cost (Painuly, Gadgil, and Natrajan 1985b). Apart from this, it was observed in the case of solar cookers that if the usage level goes down, the commercial energy requirements to manufacture solar cookers as a proportion of noncommercial energy substituted by them, increases rapidly (Painuly and Rao 1985a).

A commercially viable solution for storage of solar energy has yet to be found and hence, its use suffers from unreliability, inconvenience, and rigid timing. Therefore use of solar energy can be maintained only at a small scale, to keep the awareness level high. This will help in switching over to solar technology at an appropriate time.

Wind Energy. Being a tropical country, average wind speeds are low in India. However, there is scope for use of wind power in water pumping for irrigation. Detailed surveys will be required, to find suitable areas for operation of windmills. Field tests are in progress in several states. Present costs of windmills are quite high-$1180 (Revelle 1979)- and need to be reduced before widespread usage can be planned.

Geothermal. From the data available at present, geothermal potential is negligible. There are some indications of the presence of geothermal energy in Himachal Pradesh and development work on a cold storage unit and 5 kW power plant based on geothermal is in progress. More surveys will be needed before taking any decision to exploit this resource.

No single fuel is capable of meeting all requirements and hence, a package of fuels has to be selected. Therefore, the need for a fresh study of cost-benefits of fuels in light of developments and problems, is now faced on the fuel front. Detailed cost-benefit studies can ensure that the package of fuels selected will maximize benefits and minimize subsidy requirements, and also result in efficient use of resources.

DEMAND - SUPPLY BALANCE

General factors in balancing demand and supply of energy, and specific problems of rural areas and hill regions, are covered in this section.

Energy-Use Efficiency and Diffusion of Efficient Technology

The useful energy available to the poor is very low due to the types of fuel and appliances used. Energy-use efficiency has been taken as 7.6 percent by Makhijani (1977) and 8 percent for noncommercial (NC) by ABE (1985).

Efficiency of cooking stoves (*chulhas*) using NC fuels can be increased to 25 percent and above, as *chulhas* with efficiency 40 percent and even more have been developed. Even a 1 percent increase in efficiency of *chulhas* can save 0.25 million tons of firewood in the Himalaya region, and 3 million tons all over the country. Better design of cooking pots and pressure cooking can also increase energy-use efficiency. Modernization of tools, gadgets and efficient pumps can improve efficiency of energy-use in agriculture.

Several factors are important for success of efficient technology. First, technology has to be appropriate: cheap, and using local materials and skills. If necessary, modifications should be made to meet local requirements. Second, interveners play an important role in acceptance of technology. People who already have a role for intervention in village life like local politicians and religious persons can play an effective role in introduction and acceptance of technology (Roy 1982). Third, it has to be understood that adoption and absorption of technology is a slow process, especially in rural areas which are hardly exposed to the fast-changing lifestyle of urban areas. Also, compatability with the present system is necessary. Thus, the " technology subsystem must fit into the larger socioeconomic and cultural system of a village" (Reddy 1980). Lastly, adequate and proper extension facilities are prerequisites to the success of any new technology.

Cost of Fuel and Technology

As one of the most important points, this has to be viewed in the context of affordability and actual cost of present fuel to the users, rather than using imputed labor and time costs for analysis in an economic return framework. With more than 80 percent of fuel collected by a majority of rural population at zero private cost, they cannot be expected especially the poor, to pay for new appliances and fuel on such economic analysis criteria. It is necessary to bring down the cost of most potential technologies like biogas and solar as subsidy alone cannot sustain technology in the long term.

Methodological and Data Problems

An adequate data base on such information as energy consumption, and fuel mix, which is necessary for energy planning at the macrolevel, does not exist. There are several methodological problems in collection of data on noncommercial energy, like measurement, seasonal variations, apportioning fuel among different end uses, and between collected and purchased. In addition, there is a gradual shift from animate to physical energy in the agriculture, household, and transport sectors. Therefore, there is a need for development of a sound methodology covering various energy activities and different forms of energy, to build a sound data base.

Micro vs. Macro Energy Planning: Rural Energy Centers

Divergence in fuel consumption patterns and fuel mix indicates that although aggregate planning can be done at the macro-level, microplanning has to be area-specific. The need has been recognized, and different approaches proposed in different studies: Reddy and Subramaniam (1980), Tewari and Srinath (1980), Moulik et al (1983).

It is suggested a data base be built for different patterns of energy-use activities, energy resources and technology, and consumption patterns, and that they be grouped in 15 to 20 different types. Energy packages for each of these 'different types' can be designed using an **Integrated Energy System Approach**, to serve as basic energy packages for matching areas (villages or groups of villages). Modifications can be made to suit local requirements. A three-tier agency with high expertise at the regional level, monitoring of programs at the district/regional level, and implementation at block/area (group of village) level with adequately trained staff, can form the base for transforming energy planning into reality. The energy program should be planned to dovetail with integrated development programs like IRDP.

Problems of the Indian Himalaya

In addition to the general problems discussed in the foregoing paragraphs, hill regions have to cope with additional problems:

1. As brought out by studies, domestic energy requirements in hill areas are high. Also dependence on firewood is more than in plains areas.
2. Due to topography, pump irrigation is not possible, hence dependence on dung as manure will be more (chemical fertilizers need more water). Therefore, direct use of dung as fuel needs to be restricted.
3. For firewood alternatives like coal and LPG, distribution is a major problem. This is because villages are small and sparsely populated. Further, road transport (using diesel fuel) will be required to transport these over long distances.
4. Distribution is also a problem in many villages for community biogas for the same reason (sparse population). In addition, as temperature in winter is low, output of biogas is expected to be poor with existing technology.
5. The solar energy availability may be for a comparatively shorter period due to topography. In some villages the sun may set too early due to hill peaks.
6. The increased population and overgrazing of land by cattle, coupled with increasing industrial wood requirements has already increased the yield requirements beyond regeneration capacity in several areas. At the same time, population pressure has brought more area under cultivation (Shah 1982). Therefore, adequate land may not be available for village woodlots in all villages.

All these specific problems and characteristics of the Himalaya region will have to be kept in view while designing packages of integrated energy. This calls for specially trained staff and a specialized agency to provide support to this region.

SUMMING UP

The microstudies indicate the divergent nature of energy consumption patterns at the village level, and macrostudies, the overall picture of consumption. Therefore, although macrodata can be used for aggregate level planning for funding and technical requirements, uniform prescriptions and packages cannot work at the microlevel.

The demand is expected to increase and reach much higher levels in future (up to 2.5 times or more in the next 15 years) due to population increase and per capita consumption. Adequate supply arrangements are required for a reasonable level of quality of life to be provided to rural people. The supply potential is adequate but needs to be developed to meet increasing energy requirements. Several issues need to be resolved before energy demand-supply balance can be obtained. Area/village group-specific packages are necessary to meet specific requirements. An organizational set-up to implement and monitor the program is also needed. The Indian Himalaya has its own peculiarities in energy consumption patterns and presently available and potential energy sources/technologies. Therefore, an agency at the regional level should be specialized in these hill-specific energy characteristics.

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SUBREGIONALIZATION OF THE INDIAN HIMALAYA

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INTRODUCTION

Regionalization is an exercise in aggregation of small unit areas having certain similar characteristics into larger units, or disaggregation of larger areal units, such as continents or countries, into smaller units. The essential principle of the process of aggregation and disaggregation is that of maximum homogeneity or similarity in the characteristics among the areal units forming regions and sharp contrasts (or heterogeneity) between the regions thus delineated.

Homogeneity and heterogeneity are relative terms and have to be used with caution because of the ambiguity involved in the regional concept itself. For example, a formal region delineated on the basis of similarity in one or more physical characteristics (rock types, topography, rainfall, etc.) can and should be divided and regrouped to form a functional region which has properties of similarity on the basis of organization of its sociocultural and economic activities by the people inhabiting the region. The organization of these activities manifests itself in the emergence of a few human settlements as nodes or focal points with their relatively distinct spheres of influence. This process by which formal regions are tranformed into functional regions sets the stage for economic development.

Delineation of regions and subregions into formal and functional characteristics, and their characterization, becomes essential in understanding and evaluating their natural characteristics and human responses. Thus, while preparing a regional perspective of development for a 15- to 20-year period, the natural environment and its relationship to physical and human resources have to be kept in view. Terms such as ecology and environment, in the context of development, have to take into account this dynamic aspect of man-environment relations rather than treating man and environment in isolation. Such an approach is appropriate for regionalization of the Himalaya.

In addition to the concept of homogeneity, the concept of hierarchic interdependence is equally important because all the related elements that lend distinctiveness to the region are not uniformly distributed and they exert their influence over areas of different scale--macro, meso, and micro. For example, while the major natural regions of India are delineated on the basis of climate, subregions within them are identified on the basis of topography, soils, and vegetation. This is true of the Himalaya as well, with an added feature of ecological hierarchy of regions on account of vertical zonation of land use, as well as horizontal variations in the formation of complex drainage systems and tributary valleys of large rivers. In the context of economic interdependence, depending on the nature of the resource base, levels of its utilization, and socioeconomic development of the people, small areal units tend to establish space relations with continous neighbors whose economic activities are complementary. This principle of continuity is also relevant in the context of integrated development of the Himalaya.

In regionalization, measurement of association among different elements of the regional structure should be attempted qualitatively and quantitatively. Large-scale topographical maps, aerial photographs, and satellite imageries are indispensable tools for generating a wealth of information about topographical features, water, mineral, and forest resources, broad land use, distribution of human settlements, and infrastructure such as roads. This information can be quantified and the data aggregated to the level of administrative units by adapting the natural boundaries to those of the nearest boundary of the administrative unit. Scales of maps and the choice of administrative unit (e.g. village, village clusters, *tahsil* (revenue unit) or Development Block, District, and so on) would depend on the objective of the study. Thus, to enhance the operational utility of the exercise in regionalization, the boundaries of regions, subregions, and within them small tracts, should be adapted to the administrative boundary.

Regionalization, once attempted, should be tested for its accuracy or validity once in at least five to ten years as the regional boundaries are subject to change due to changes in man-environment relations with advances in technology. In the initial stage of development, the influence of the natural environment is somewhat deterministic. Cultivated areas are mostly in small patches of valley plains or clearings around human settlements, and the settlements themselves are distributed in conformity with the pattern of drainage and terrain conditions. Subsequently, transport routes develop within and between regions, and the utilization of resources makes it possible to overcome the deterministic influence of the natural environment, resulting in the emergence of functional-economic regions which cut across physical barriers. The linkage between Jammu and the Kashmir Valley provides the best example of the impact of technology on natural environment. Likewise, in the northeastern region, the economic focus is the Assam Valley, though the smaller states and Union Territories are distinct in their physiographic characteristics. Even though metaphysical dubiety may surround the whole concept of the region, for practical purposes regions exist, and if they did not they would have to be invented.

NEED FOR SUBREGIONALIZATION OF THE HIMALAYA

The Himalaya comprises a vast system of mountain ranges, highly dissected, having deep gorges and narrow valley plains, and in certain areas too complex to be amenable to regional differentiation from the macro to micro levels. As Ogilvie observes, "nowhere in the world are the small natural regions more sharply separated than in the

Himalaya" (Ogilvie 1938). Because of the distinct differences in geological structure, heights, slope, and natural vegetation, the approach to subregionalization becomes exceedingly complex and challenging. The approach can be one or all of the following considerations, depending on the objective of the study:

- Subregionalization on the basis of altitude and slope
- Longitudinal differentiation of mountain ranges and valleys
- Latitudinal differentiation on account of the width of the Himalaya

In all the attempts toward regional delineation of India, the Himalaya stands out as a distinct major region which is marked off from the northern alluvial plains of the Indus, the Ganga, the Brahmaputra, and their tributaries. Further subdivision has been attempted rightly on the basis of natural factors giving weightage to geological structure and topography, and drainage within the overall influence of climate. Such an approach can be considered an attempt to evaluate the impact of physical factors and human response, such as land slope and bringing those lands under cultivation, soil erosion and creation of embankments, spatial arrangement of human settlements, efforts to provide infrastructure facilties and amenities, and so on. Characterization of natural regions and subregions also provides a basis for an assessment of physical resources of the area and to prepare a strategy for development appropriate to those regions and subregions. Under conditions of extremely rugged terrain and temperate climatic conditions, human settlements are small and scattered, and population density is low. Such areas of small settlements distributed within drainage basins of tributary streams should be the lowest order areal units for integrated development of land use, human settlements and infrastructure such as transport, power, and other energy resources.

Second, the vast east-west expanse of the Himalaya falls within the jurisdiction of different political administrative frameworks--international, interstate, and intrastate. As a result, the development of water and power resources, land use and soil conservation, utilization of forest and minerals, and the problems of environment, need coordinated development. These aspects of development should be dovetailed within the overall strategy for the development of the Himalaya with that of the concerned political administrative unit.

It is possible to measure intraregional and interregional variations in overall levels of economic development, with the help of a variety of socioeconomic variables related to the development process. The Himalayan region, with its sharp variations in levels of interregional transactions, presents evidence of the emergence of function-economic subregions. Boundaries of these subregions would be nearly coterminus with those of natural boundaries, such as the major and minor water-sheds which insulate the human settlements in performing their socioeconomic activities.

An important aspect to be dealt with in subregionalization is the identification of the elements of the regional structure and their distributional pattern. Boundaries are then drawn according to variations in intensity of occurrence, such as high, medium, and low. These elements and their relative importance at the local, regional, national, and international level also need to be evalutated, so that the subregions can then be arranged in a hierarchic order. For example, scattered human settlements and cleared patches of cultivation or grassland mostly to suit the local needs are important at the local level. Areas suitable for the development of major hydroelectric projects or of economic minerals are of national and international importance. The Karewas (plains fringing the Jhelum River in the Kashmir Valley) are of regional importance for rainfed crops in unirrigable parts, and for the cultivation of rice, maize, and saffron.

Precise delineation of subregions of different orders is exceedingly complex because of the sharp differences in physical characteristics and the vast extent of the Himalaya. Even when these boundaries are drawn closely following the physical characteristics such as slopes and natural vegetation, they tend to be smooth, unlike administrative boundaries of villages, *tahsils* or districts. Subregions bounded on these considerations are very valuable to begin with, as they serve to characterize these subregions according to their inherent characteristics. These characteristics can be quantified by using small grids--squares or rectangles--and the groups of such grids falling within the administrative units are then used for quantification of the qualitative data relating to different characteristics of these subregions. It must be mentioned however that subregionalization and characterization of regions is only a beginning in understanding and evaluating those elements of the regional structure which influence, directly or indirectly, the problems of development of the region. The following stages in subregionalization are suggested, keeping in mind the strong bias toward physical planning approaches in the case of the Himalaya.

Macroregional Delineation

Delineation of regional boundaries should be attempted on the basis of the information available from small-scale maps of 1: 1,000,000 and satellite imageries with respect to topography, drainage, broad land use, locations of human settlements, transport lines, and so on. These boundaries are then adapted to those of the nearest district boundaries for grouping districts on the basis of these characteristics, and interpretation of the available secondary data on demographic, socioeconomic, and infrastructural facilities and amenities. Since these districts, and in turn the subregions comprising groups of districts, fall in different states and union territories, subregionalization would also serve to evaluate the problems of interstate and intrastate cooperation particularly in the context of development of water and power, forest, and mineral resources.

Mesoregional Delineation

Within the subregions identified on the basis of the above exercise, further refinement of the regional boundaries becomes necessary to ensure that the subregions portray the ground reality to the extent possible. In this case, the large-scale topographical maps of the Survey of India (1: 200,000) and the satellite imageries would be valuable to identify smaller unit areas within the overall subregional framework. These boundaries should then be adapted to those of the *tahsil* or Development Block boundaries for data aggregation and analysis of the regional structure.

Microregional Delineation

Each areal unit comprising a narrow enclosed valley plain or a distinct natural unit can be considered a microregional unit for preparing an integrated development plan with energy as an important component.

For purposes of identification and adoption of the microregion as a unit for planning, a Development Block, or *tahsil* would be ideal. Large-scale maps (1: 50,000 scale) of the Survey of India, aerial photographs, and satellite imageries would be necessary to build an up-to-date resource inventory in its spatial framework.

SUBREGIONAL DELINEATION OF THE HIMALAYA

There have been attempts in the past--mainly by geographers--toward delineation of subregions of the Himalaya in the context of understanding the regional geography of India. In all those studies, the Himalaya is considered one of the macroregions marked off from the northern alluvial plains and having its own climatic, vegetal, sociocultural, and economic characteristics. The parallel mountain ranges and valleys have also been identified into three subregions, as the Himalaya varies in width from 150 km to 400 km.

South-North

The Siwaliks (up to 1830 meters). These are the southernmost foothills of the Himalaya, formed by river-borne deposits from the rising Himalaya. This area was subsequently folded and faulted by earth movements. The faulted edges are marked by abrupt slopes. The average elevation is about 600 meters, though internally the parallel ridges rise to about 1500 meters. To their north, the hill ranges descend to give rise to flat-floored valleys which are the main areas of intensive cultivation and dense population. These valleys are locally known as *duns* (e.g. Dehra Dun).

From the point of view of energy resources, an integrated approach is needed for the development of livestock, natural vegetation, tributary streams and their gradients, and the characteristics of land form and slopes. Within the Siwaliks subregion, there are a large number of valleys of small tributary streams where the population is scattered in small hamlets. These valleys are separated from the watersheds and often have no settlement on account of the steep gradient of tributary streams. The focus is on the settled valleys, while the Siwaliks and their role in development need to be assessed in the context of the overall strategy for the development of the states in which they form distinct subregions.

Lesser Himalaya (1830 to 3050 meters). These massive mountain ranges rise abruptly from the Siwaliks to a height of 5000 meters. Between 1000 to 5000 meters, this area is formed of more complex patterns of mountains and valleys, which run in all directions. The southern slopes in general are bare, while the northern slopes are covered with thick forests, possibly on account of their being insulated from the relatively densely populated valleys beyond which these ranges rise abruptly. There are patches of snow-covered peaks along the mountain ranges. The width of the region is about 75 km.

Population density is very sparse in this region, with scattered hamlets on patches of flatlands, mostly along the lower slopes of tributary valleys.

Greater Himalaya. The region is also known as *Himadri*, indicative of its being a permanently snow-covered mountainous region. Landforms, carved out of permanent snow-cover and glaciation, are characteristic convex slopes and hanging valleys with deposits of moraines. Erosion is therefore much less than in landforms carved by stream action. The western and eastern limits of the Greater Himalaya terminate abruptly, displaying the folded nature of the mountains and periodic uplift. The glaciers in the region are the largest in the world, particularly in the western part, or Karakoram area. Some of them are not only large, but descend to low levels as in Kashmir (2135 to 2440 meters). To the north, this region marks the edge of the massive northern plateau against which the folded mountains of the Himalaya have been thrust.

The rivers and their tributary streams in this region are marked by deep gorges and mature valleys in places, and showing distinct expressions of river capture and swift flow as a source of vast potential for hydropower and irrigation water.

Because of height and vertical zonation of vegetation from grassland to alpine forests, the variations in plant and animal resources also need intensive evaluation at the macro to micro level of land units.

West-East

Subregionalization of the Himalaya from west to east is more important because of the vast extent, stretching over 2500 km between the Indus and the Brahmaputra. In delineating these subregions, climate, topography, and vegetation are important. Climatically, the region varies from relatively drier areas in the west (Jammu and Kashmir) to the area having highest rainfall in the northeastern mountain areas. The following subregions are identified with certain evidence of the hierarchical role of rainfall, topography, and vegetation in their influence:

Western Himalaya. This subregion extends from Jammu and Kashmir to approximately the border of Nepal. The Kali river in Nepal is its eastern limit.

Central Himalaya. This comprises most of Nepal. Its eastern boundary is demarcated by the high transverse range--the Singalia.

Eastern Himalaya. More humid climate, lower heights, less snow-cover, and dense forests serve to demarcate the rest of the Himalaya. This comprises the Sikkim

Himalaya, Darjeeling Himalaya, Bhutan Himalaya, and Northeastern Himalaya, comprising the territories of Arunachal Pradesh, Nagaland, Manipur, Mizoram, and Tripura. Structurally, Meghalaya does not belong to the Himalaya ranges because it is a detached block of the peninsular plateau; yet on account of its situation and formation as the mountain mass of northeast India, it is included in the Himalaya region. The regional structure and development problems are similar, though genetically they are different.

Within the macroregions of the Himalaya identifiable on the basis of climate, macro-geomorphological features and natural vegetation, the following schemes of subregions have been identified in earlier exercises in regionalization using mainly landform features of the lower order (meso and micro). These subregions and their salient characteristics are enumerated below.

REVIEW OF PAST ATTEMPTS AT SUBREGIONALIZATION

O. H. K. Spate (1967) introduced the concept of macro, meso, and micro regions in subregionalization of India. Within the three macroregions of India (the coastal plains, the peninsular plateau, and the northern mountains) the Himalaya is subdivided into 6 first-order regions, 18 second-order regions, and 43 third-order regions. An attempt is also made to further subdivide them into distinctly identifiable land units (Appendix A).

On a less intensive scale, S. P. Chatterjee (1965) has identified three major regions--Western, Central, and Eastern--within which 11 second-order regions have been identified (Appendix B). Some of those correspond broadly with the second-order sub-regions delineated by Spate, though they correspond with mainly the political boundaries of states or parts of states (e.g. Kumaun Himalaya, Darjeeling Himalaya, Manipur Hills, Nagaland, and so on.) Some states in northeast India are comparable to the size of a district or group of smaller districts elsewhere; this may be an advantage for preparing the spatial and sectoral development plan for the state from below.

R. L. Singh (1971) has attempted a detailed scheme of sub-regions in which 14 first-order, 40 second-order, and within them 109 third-order, have been identified (Appendix C). Here again the principles of delineation are based on natural characteristics according to their relative importance and interrelations mentioned earlier. While the first- and second-order regions appear to be comparable, and reflect regional realities, the third-order regions are of varied scale. For example, in the Kashmir region apart from the two first-order regions, which distinguish the Kashmir Valley and the Jammu region, delineation of three third-order regions, such as the Jhelum Plain, the Karewas, and the mountainous rimlands are very important. The rimland has dense forest cover and along with the utilization of the Karewas for grass and grazing purposes in unirrigable parts, the region has potential for the exploitation of biomass energy. In the U. P. Himalaya, the third-order subregions are mostly the valleys of tributary streams, which are large in number and do not reflect the relationship of several watershed areas which might show common characteristics in terms of slope and land use.

REGIONAL VARIATIONS IN LEVELS OF DEVELOPMENT (Table 1)

While the foregoing analysis provides subregions of different scales based on natural factors as they are relevant for the evaluation of physical resources, an attempt is made to identify regional variations in levels of development using 11 variables relating to demographic, social, and economic characteristics as available from census records (1971).[1] The district is adopted as the unit for compiling data and appropriate ratios have been used while ranking districts on the basis of each characteristic.

Composite rank scores are calculated and the districts within each state are grouped according to uniformity or similarity in composite rank score. Districts with low values on composite rank scores are considered relatively developed while those with higher values are treated as less developed.

Results of this study, despite limitations, provide certain valuable evidence of the underlying relations between the natural environment and human response derived from the variations in the values of socioeconomic variables used in this study (Appendix D). Population density and the size of human settlements reflect the influence of the natural environment, while other variables are related to socioeconomic characteristics. Salient features of the variations in levels of development are outlined below.

In Jammu and Kashmir, 10 districts fall into 4 levels of development, with Srinagar and Jammu occupying the relatively developed category; Ladakh and Doda are least developed. The three subregions from south to north which conform to sharp division according to topographical features are evident. Within Himachal Pradesh, Simla, as could be expected, belongs to the developed category in contrast to the contiguous northern districts of Chamba, Lahul, Spiti, and Kinnaur which are least developed. Incidentally, this subregion is also contiguous to Ladakh in Jammu and Kashmir as an extension of the same characteristics of the Lesser, and to some extent, the Greater Himalaya.

The hill region of Uttar Pradesh has three subregions, with Nainital and Dehra Dun belonging to the developed category, while Uttar Kashi, Chamoli, and Teri Garwal can be grouped into the least developed category.

Table 1: **Indian Himalaya: Development Pattern**
(Intrastate and Interstate)

Development Level	Jammu & Kashmir	H.P.	Hill Region of U.P.	North Bengal	Northeast India
I (Highest) (33)	Srinagar (38) Jammu	Simla (35) (22)	Nainital (32) Dehra Dun	Darjeeling (17) (30)	Tripura (26) Mizoram
II	Anantnag (47) Kathua (43)	Bilaspur (43) Kangra (45)	Pithoragarh (46) Almora (44) Pauri Garwal (41)	Cooch Bihar (26) Jalpaiguri (23)	Manipur (36) Meghalaya (38)
III	Udhampur (58) Baramula (61) Poonch (61) Rajouri (65)	Mandi (54) Kulu (57) Sirmaur (58)	Uttar Kashi (62) Teri Garwal (62) Chamoli (51)	-	Nagaland (44)
IV	Ladakh (74) Doda (70)	Lahul (63) Kinnaur (64)	-	-	Arunachal Pradesh (55)
V (Lowest)	-	Chamba (76)	-	-	-

Note: Figures indicate composite score.

In North Bengal, Darjeeling District stands out in sharp contrast to Cooch Bihar and Jalpaiguri, the former being relatively developed. Entire North Bengal, in fact, forms a part of the Eastern Himalaya with Sikkim as its contiguous neighbor. The Tista and the Chimbu Valleys are ideal subregions for illustrating the need for integrated development of water and land resources.

In the northeast, the paucity of data limits subregionalization of the states and union territories, though contrasts in terrain, land use, water resources, and socioeconomic characteristics are as conspicuous as in the relatively large subregions of Kashimir, Himachal, and the U.P. Himalaya (e.g. valley plain and tribal hills areas of Manipur or the Garo, Khasi, and Jaintia hill regions of Meghalaya).

ENERGY RESOURCE POTENTIALS OF THE HIMALAYA

The attributes of development, listed by district for each of the subregions, bring out certain common characteristics of the Himalaya region which have a bearing on the development of energy resources for the region's population and those required for development of other regions of the country.

The structural characteristics, landforms, and drainage, evolved out of continued uplift over 50 to 60 million years, have provided the region with vast potential for the development of water and power resources. There are possibilities for a large number of minihydel projects in Himachal and the U. P. Hill region for the benefit of the population living in the area, with a view to diversify the employment base which is still dependent largely on subsistence agriculture and livestock economy (Appendix D). Because of the slow uplift of the Himalaya, the drainage pattern in many places does not follow the normal pattern of parallel mountain ranges separated by river valleys. Innumerable river captures, steep-sided valleys, escarpments, and deep gorges extending to cover 6000 meters, and the ungraded streams marked by waterfalls and rapids need to be systematically evaluated for the purposes of preparing a strategy for the development of energy resources.

With regard to nonconventional energy resources available from biogas plants and conversion of woody biomass into solid, liquid, or gaseous fuels, physical planning of land use and settlements needs priority, for which the accompanying Table provides evidence of low levels of development (e.g. very small villages and low levels of literacy, urbanization, and employment). The population, under the deterministic influence of the natural environment, lives close to nature for meeting the minimum requirements of fuel, land cultivation, rearing animals and so on. Low levels of human resource development marked by low levels of literacy, inaccessibility, and isolation have to be assessed from the grass roots level.

SUGGESTED OUTLINE FOR FURTHER WORK

Against this background, an outline of study is suggested leading to the formulation of a spatial development model in which alternative sources of energy would be a built-in component.

Regional delineation and characterization of regions is only a beginning with a view to reorient and evaluate the available information on spatial considerations. This is necessary because the data generated by various organizations are mostly aggregated on the basis of administrative units falling within different states and union territories. Space affinity of such data has to be assessed with reference to the objective mentioned above. From the first report, prepared by various contributors, a coordinated approach for the preparation of a normative energy-oriented development strategy for the Western, Central, and Eastern Himalaya and subregions, to the level of first- and second-order regions, needs to be formulated. This should be followed by case studies for selected microlevel regions comparable to the size of Development Blocks or microwatersheds.

The following design of the study is recommended in the second stage of the Project.

Development Strategy for a Microregion

Large-scale topographical maps (1:50,000 and 1:200,000), aerial photographs, and satellite imageries should be used. Evaluation of the relations between land cover and landforms, drainage pattern, and human settlements, their socioeconomic attributes, and their spatial organization is necessary; the existing source and level of use of energy and potential for development are some of the themes for detailed investigation. Field enquiry in sample households and sample survey of economic activities have to be conducted with the help of questionnaires. For sampling purposes, the subregions provide the area basis.

Development Strategy for Mesolevel Regions

The mesolevel subregions should comprise groups of Development Blocks, or in some cases districts, of relative homogeneity with respect to landform and land use. For mapping purposes, the scale of maps should be at least 1:200,000. Resource inventory based on the data obtained from topographical maps and satellite imageries at this scale would serve to evaluate the problems and potentialities for the development of physical resources and their impact on socioeconomic development of the subregions of the Himalaya. Microregional studies would provide a wealth of quantitative and qualitative data from which certain norms and coefficients relevant for the Himalaya region can be determined. Viewed from these considerations, microregional studies of the size of micro and mini watersheds, or of Development Blocks comprising several small drainage basins, should be initiated on a sample basis to build case studies relating to the development of the Himalaya region.

ENDNOTES

1. A similar exercise needs to be done more intensively using tahsil data for 1981 and also evaluating the pattern of changes in these characteristics. The variables selected are: population density, percentage of urban population, percentage of small-sized villages (less than 200to 500 people), literacy (total, female, rural, and urban), workers, percentage of workers engaged in secondary and tertiary activities (Appendix D).

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APPENDIX A

Subregionalization of the Himalaya according to O. H. K. Spate

I. KASHMIR

1. Poonch and Jammu

- a) Siwalik zone
- b) Sub-Himalayan zone
    - i. foothills: Jhelum gorge, Tawi Valley
    - ii. mid-Chenab Valley

2. Pir Panjal Range

3. Vale of Kashmir

- i. border ranges and valleys
- ii. vale: Karewas terraces, Jhelum marshes

4. Main Himalayan Mass

- a) Nanga Parbat massif
- b) Great Himalaya
- c) Upper Chenab Valley
- d) Zanskar Range
    - i. Range proper
    - ii. Deosai plains
    - iii. Rupshu

5. Gilgit - Hunza

- a) i. Astor Valley
    - ii. Indus Kohistan: Indus gorge
- b) i. Gilgit-Hunza Valley
    - ii. Hindu Kush

II. KARAKORAM

1. Ladakh

- i. Indus furrow
- ii. Ladakh Range

2. Karakoram

- a) Baltistan (Northern Shigar Valley)
- b) Shyok-Nubra Valleys
    - i. Main valley - Shyok dam
    - ii. Change-Cenmo Valley
    - iii. Harong Valley
- c) Karakoram massif
- d) Tibetan plateau
    - i. Depsang and Lingzi-tang plains
    - ii. Pangong rift

III. CENTRAL HIMALAYA

1. Himachal Pradesh

- a) Siwalik zone: and the duns
- b) Sub-Himalayan zone
    - i. main valleys - Chandra (Kulu)
      Beas (Mandi and Lahul)
    - ii. main ranges - Eastern Pir Panjal Dhaoladhar
    - iii. Sutlej valley
- c) Upper Sut
    - i. Spiti
    - ii. Hundes - Rakas and Manasarowar lakes

2. **Kumaon** (Hill region of U.P)

- a) i. Siwaliks
  - ii. Dehra Dun
- b) Sub-Himalayan zone: Yamuna Ganga, Kali valleys
- c) High Bhotiya valleys

3. **Nepal**

- a) Siwalik zone
- b) Pahar - Kathmandu Valley, minor duns
- c) High Himalaya

IV. EASTERN HIMALAYA

1. **Kosi Basin**

- i. Siwaliks and longitudinal valleys
- ii. Arun gorge
- iii. Everest massif

2. **Darjeeling - Sikkim**

- i. Tista Valley: Singaliya ridge, Darjeeling Hills, Tista Valley proper Dongkhya range.

- ii. Chumbi Valley

3. **Bhutan and Assam Himalaya**

V. ASSAM-BURMA RANGES

1. **Border Hills:**

- i. Patkoi hills
- ii. Naga hills
- iii. Chin hills
- iv. Lushai hills
- v. Chittagong hills - Manipur basin

2. **Barail Range**

VI. SHILLONG PLATEAU

1. Garo hills
2. Khasi hills
3. Jaintia hills

Source: Spate, O. H. K. and A. T. A. Learmonth (1967), India and Pakistan, Methuen, London.

APPENDIX B:

Subregionalization of the Himalaya according to S.P. Chatterjee

I. WESTERN HIMALAYA

1. North Kashmir Himalaya
2. South Kashmir Himalaya
3. Himachal Himalaya
4. Kumaun Himalaya (Hill Region of U.P.)

II. CENTRAL HIMALAYA

1. Nepal Himalaya

III. EASTERN HIMALAYA

1. Sikkim Himalaya
2. Darjeeling
3. Bhutan Himalaya
4. Assam Himalaya (now-Arunachal Pradesh for the most part)
5. North-Eastern Range
    - a) Purvachal
        - i. Eastern part of Arunachal Pradesh ('Purva Nepal')
        - ii. Nagaland
        - iii. Manipur hills
        - iv. North Cachar hills
        - v. Mizo hills
        - vi. Tripura hills
6. Meghalaya
    - a) Garo hills
    - b) Khasi-Jaintia hills
    - c) Mikir hills

Source: Chatterjee, S. P. (1965) 'Physiography' Chapter II in Gazetteer of India, Vol. I - Country and People, Publication Division, Ministry of Information and Broadcasting, Govt. of India, Delhi, pp. 1-66.

APPENDIX C:

Subregionalization of the Himalaya according to R. L. Singh

I. KASHMIR REGION

1. **Kashmir Region South**
    - a) Kashmir Valley
        - i. The Jhelum Plain
        - ii. The Karewas
        - iii. The Rimlands
    - b) Jammu-Mirpur Regions
        - i. The Foothill Plains
        - ii. The Siwaliks
        - iii. The lesser Himalaya or Pir Panjal Region
2. **Kashmir Region North**
    - a) Zaskar - Ladakh Region
        - i. The Great Himalayan - Zaskar Region
        - ii. The Sindhu Furrow
        - iii. The Ladakh Range
        - iv. The Upper Shyok Valley
    - b) Deosai - Skardu Region
        - i. The Deosai Highland
        - ii. The Deosai Plain or Skardu Region
        - iii. The Astor Valley
        - iv. The Nanga Parbat
    - c) Gilgit - Baltistan Region
        - i. The Lower Shyok Valley
        - ii. The Karakoram Range
        - iii. The Shigar Valley
        - iv. The Gilgit - Hunza Valleys
        - v. The Hindukush Region
        - vi. The Gilgit Massif - Sindhu Gorge
    - d) Aksai Chin Region
        - i. The Suget Range

- ii. The Soda Plain
- iii. The Ladakh Plateau
- iv. The Kara Kash Valley

II. HIMACHAL REGION

1. **Himalayan Himachal**

   a) Chandra-Bhaga Basin
      - i. Lahul
      - ii. Pangi

   b) Ravi Basin
      - i. Brahmaur region or Ravi Chamba East Region
      - ii. Chamba region or Ravi Chamba West Region

   c) Beas Basin
      - i. Kulu-Banjar Region or Kulu - Beas Region
      - ii. Mandi - Beas Region
      - iii. Dera - Gopipur Beas Region
      - iv. Kangra - Palam Region

   d) Himalayan - Sutlej Basin
      - i. Simla - Rampur Region
      - ii. Bilaspur - Nalagarh Region

   e) Yamuna Basin
      - i. Tons - Pabar Region
      - ii. Giri - Yamuna Region

2. **Trans-Himalayan Himachal (Spiti-Kinnaur Himachal)**

   a) Trans-Himalayan Sutlej Basin or Spiti-Sutlej Basin.
      - i.Spiti Region
      - ii. Kalpa-Sutlej Region

   b) Malung Valley

III. U.P. HIMALAYA

1. Himadri

   a) Himadri Ranges
      - i. Bandarpunch Block
      - ii. Kedarnath-Badrinath Block
      - iii. Kamet-Hathiparvat Block
      - iv. Dronagiri-Nanda Devi-Trisul Block
      - v. Lipulekh-Kalapani Block

   b) Himadri valleys
      - i. Upper Tons Valley
      - ii. Upper Yamuna
      - iii. Janhavi Valley
      - iv. Uppwer Bhagirathi Valley
      - v. Upper Billanga Valley
      - vi. Upper Mandakini Valley
      - vii. Vishnuganga Valley
      - viii. West Dhaulinganga Valley
      - ix. Goriganga Valley
      - x. East Dhaulinganga Valley
      - xi. Upper Kaliganga Valley

IV. HIMACHAL

   a) Tons-Yamuna Basin
      - i. Eastern Tons Basin
      - ii. Yamuna Basin

   b) Bhagirathi-Alaknanda Basin
      - i. Bhagirathi Basin
      - ii. Bhillanga Basin
      - iii. Mandakini Basin
      - iv. Alaknanda Basin
      - v. Pindar Basin
      - vi. Nayar Basin
      - vii. Ganga Basin

   c) Ramganga-Kosi Basin
      - i. Ramganga Basin
      - ii. Kosi Basin
      - iii. Gola Basin

   d) Sarju-Kali Basin
      - i. Sarju Basin
      - ii. Ramganga Basin
      - iii. Goriganga Basin
      - iv. Kali Basin (W)
      - v. Ladhiya Basin

V. SIWALIKS

- a) Yamuna-Ganga Tract
  - i. Dun Valley (Dehra Dun)
  - ii. Yamuna-Ganga Tract
- b) Ganga-Ramganga Tract
- c) Ramganga-Kali Tract

VI. EASTERN HIMALAYA

- a) Darjeeling - Sikkim
  - i. Singalia Range
  - ii. Donkhya Range
  - iii. Darjeeling
  - iv. Kalimpong
- b) Bhutan
  - i. Punaka-Thimpu region
  - ii. Tongsa Region
  - iii. Phuntsoling region
  - iv. Devanagiri region
  - v. Homolhari-Kulakangri region

VII. NORTH-EASTERN HIMALAYA (Arunachal Pradesh)

- a) Dafla region
- b) Miri region
- c) Abor region
- d) Mishmi region

APPENDIX D
Variations in Levels of Development According to Different Indicators

I. WESTERN HIMALAYA

1. Jammu & Kashmir

Density km^2 percent		Villages (<500 persons) percent to Total		Female Literacy (percent)	
1. Srinagar	274.70	1. Doda	72.5	1. Jammu	20.62
2. Jammu	231.18	2. Ladakh	70.21	2. Kathua	12.25
3. Anantnag	154.60	3. Jammu	68.30	3. Ladakh	7.81
4. Baramula	104.00	4. Kathua	65.64	4. Srinagar	5.83
5. Kathua	103.60	5. Udhampur	62.85	5. Rajouri	5.00
6. Punch	102.95	6. Srinagar	60.96	6. Anantnag	4.81
7. Rajouri	81.05	7. Rajouri	58.75	7. Doda	4.48
8. Udhampur	74.47	8. Anantnag	53.84	8. Baramula	3.87
9. Doda	28.60	9. Baramula	52.44	9. Punch	3.08
10. Ladakh	1.09	10. Punch	32.27	10. Udhampur	2.67

Urbanization percent to Total		Literacy (Total) percent		Rural Literacy (percent)	
1. Srinagar	51.12	1. Srinagar	82.69	1. Jammu	22.06
2. Jammu	26.14	2. Jammu	30.34	2. Kathua	19.48
3. Kathua	9.10	3. Punch	23.66	3. Anantnag	13.61
4. Anantnag	8.91	4. Kathua	21.62	4. Rajouri	13.26
5. Baramula	8.53	5. Rajouri	17.77	5. Udhampur	12.24
6. Udhampur	8.38	6. Anantnag	14.97	6. Doda	11.90
7. Punch	8.08	7. Doda	13.88	7. Punch	11.85
8. Ladakh	7.50	8. Baramula	13.16	8. Baramula	11.54
9. Doda	5.69	9. Udhampur	6.39	9. Ladakh	10.99
10. Rajouri	3.81	10. Ladakh	3.95	10. Srinagar	10.91

Urban Literacy (percent)	
1. Jammu	53.74
2. Udhampur	52.46
3. Doda	46.67
4. Punch	45.65
5. Rajouri	44.58
6. Kathua	43.20
7. Ladakh	34.18
8. Srinagar	32.04
9. Baramula	30.51
10. Anantnag	28.98

Workers in Industry to Total (percent)	
1. Srinagar	15.71
2. Kathua	7.08
3. Anantnag	6.17
4. Jammu	6.15
5. Udhampur	6.14
6. Baramula	4.39
7. Doda	2.58
8. Punch	2.31
9. Rajouri	2.15
10. Ladakh	1.94

Workers to Total (percent)	
1. Ladakh	43.82
2. Doda	36.09
3. Udhampur	31.19
4. Anantnag	31.11
5. Baramula	31.05
6. Srinagar	28.86
7. Punch	27.76
8. Rajouri	27.65
9. Kathua	26.68
10. Jammu	24.44

Workers in Services to Total (percent)	
1. Srinagar	36.57
2. Jammu	36.36
3. Kathua	21.26
4. Udhampur	16.57
5. Anantnag	16.28
6. Baramula	15.96
7. Ladakh	13.21
8. Rajouri	11.29
9. Punch	11.16
10. Doda	9.04

2. Himachal Pradesh

Density km^2 per cent	
1. Bilaspur	166.92
2. Kangra	158.05
3. Simla	153.31
4. Mandi	128.22
5. Sirmaur	86.72
6. Kulu	35.38
7. Chamba	31.14
8. Kinnaur	7.59
9. Lahul Spiti	1.95

Villages (<200 persons) percent to Total	
1. Simla	90.25
2. Lahul Spiti	82.35
3. Mandi	70.67
4. Kangra	69.33
5. Bilaspur	67.83
6. Sirmaur	63.83
7. Chamba	52.44
8. Kinnaur	9.09
9. Kulu	1.18

Literacy Total (percent)	
1. Simla	38.55
2. Kangra	37.52
3. Bilaspur	32.85
4. Mandigar	30.68
5. Lahul Spiti	28.51
6. Kinnaur	27.71
7. Kulu	24.37
8. Sirmaur	24.36
9. Chamba	18.88

Urbanization percent to Total	
1. Simla	31.82
2. Mandi	9.35
3. Sirmaur	8.44
4. Chamba	7.36
5. Kulu	5.56
6. Bilaspur	4.88
7. Kangra	3.66
8. Kinnaur	0.00
9. Lahul Spiti	0.00

200-500 (Total) percent	
1. Kinnaur	38.96
2. Chamba	34.09
3. Mandi	25.85
4. Bilaspur	25.02
5. Sirmaur	24.97
6. Kangra	22.39
7. Kulu	18.34
8. Lahul Spiti	15.68
9. Simla	8.09

Female Literacy (percent)	
1. Simla	26.88
2. Kangra	26.67
3. Bilaspur	21.00
4. Mandi	17.16
5. Sirmaur	12.91
6. Kulu	11.06
7. Lahul Spiti	10.37
8. Kinnaur	10.37
9. Chamba	9.12

Rural Literacy (percent)	
1. Kangra	37.03
2. Bilaspur	31.59
3. Lahul Spiti	28.51
4. Kinnaur	27.71
5. Mandiri	27.34
6. Simla	25.56
7. Kulukh	22.19
8. Sirmaur	21.36
9. Chamba	15.74

Workers (percent)	
1. Lahul Spiti	64.68
2. Kinnaur	60.64
3. Kulu	48.67
4. Sirmaur	42.48
5. Bilaspur	40.50
6. Chamba	40.32
7. Mandi	39.57
8. Simla	35.78
9. Kangra	27.47

Workers in Service (percent)	
1. Lahul Spiti	39.46
2. Simla	38.07
3. Bilaspur	22.67
4. Kangra	22.14
5. Kinnaur	19.85
6. Mandi	18.86
7. Sirmaur	15.05
8. Chamba	11.16
9. Kulu	10.44

Urban Literacy (percent)	
1. Simla	66.43
2. Mandi	63.28
3. Kulu	61.68
4. Bilaspur	59.57
5. Chamba	59.04
6. Sirmaur	57.49
7. Kangra	50.62
8. Kinnaur	.
9. Lahul Spiti	.

Workers in Industry (percent)	
1. Kangra	5.97
2. Simla	5.65
3. Sirmaur	4.99
4. Kinnaur	4.63
5. Bilaspur	3.92
6. Mandi	3.52
7. Kulu	2.23
8. Chamba	2.13
9. Lahul Spiti	1.30

3. U.P. Hill Region

Density km^2 percent

1. Dehra Dun	186.94
2. Nainital	113.21
3. Almora	106.79
4. Pauri Garhwal	101.65
5. Tehri Garhwal	89.86
6. Pithoragarh	43.46
7. Chamoli	32.05
8. Uttar Kashi	18.43

Villages (<200 persons) percent to Total

1. Pauri Garwal	73.66
2. Pithoragarh	66.54
3. Chamoli	65.05
4. Almora	63.06
5. Tehri Garhwal	61.90
6. Uttar Kashi	59.23
7. Dehra Dun	54.76
8. Nainital	51.16

Literacy Total (percent)

1. Dehra Dun	43.71
2. Pauri Garhwal	32.00
3. Pithoragarh	31.87
4. Nainital	30.94
5. Chamoli	28.68
6. Almora	28.08
7. Uttar Kashi	22.05
8. Tehri Garhwal	19.28

Urbanization percent to Total

1. Dehra Dun	47.06
2. Nainital	22.12
3. Pauri Garwal	6.29
4. Almora	5.21
5. Chamoli	4.17
6. Uttar Kashi	4.05
7. Pithoragarh	3.79
8. Tehri Garhwal	2.64

Villages 200-500 Persons (percent)

1. Uttar Kashi	34.38
2. Tehri Garhwal	33.04
3. Almora	30.15
4. Chamoli	29.57
5. Nainital	28.97
6. Dehra Dun	27.25
7. Pithoragarh	26.72
8. Pauri Garhwal	23.64

Female Literacy (percent)

1. Dehra Dun	33.40
2. Nainital	20.17
3. Pauri Garhwal	16.51
4. Pithoragarh	14.62
5. Almora	11.52
6. Chamoli	9.56
7. Uttar Kash	5.44
8. Tehri Garhwal	4.91

Rural Literacy (percent)	
1. Pithoragarh	30.75
2. Pauri Garhwal	30.13
3. Chamoli	27.47
4. Nainital	27.44
5. Dehra Dun	27.20
6. Almora	25.91
7. Uttar Kashi	20.32
8. Tehri Garhwal	18.10

Workers (percent)	
1. Uttar Kashi	63.53
2. Chamoli	58.02
3. Tehri Garhwal	51.50
4. Pauri Garhwal	48.41
5. Pithoragarh	40.13
6. Almora	38.84
7. Dehra Dun	34.83
8. Nainital	33.53

Workers in Service (percent)	
1. Dehra Dun	51.57
2. Nainital	23.80
3. Tehri Garhwal	21.28
4. Pauri Garhwal	17.57
5. Pithoragarh	15.91
6. Almora	13.93
7. Chamoli	10.77
8. Uttar Kashi	9.69

Urban Literacy (percent)	
1. Almora	67.52
2. Dehra Dun	62.35
3. Pauri Garhwal	59.77
4. Chamuli	55.74
5. Nainital	33.10
6. Uttar Kashi	11.68
7. Tehri Garhwal	8.71
8. Pithoragarh	7.20

Workers in Industry (percent)	
1. Dehra Dun	9.25
2. Nainital	7.17
3. Pithoragarh	2.62
4. Almora	2.61
5. Tehri Garhwal	2.15
6. Chamoli	2.06
7. Uttar Kashi	1.81
8. Pauri Garhwal	1.48

II. EASTERN HIMALAYA

1. North Bengal

Density km^2 per cent	
1. Cooch Bihar	417.63
2. Jalpaiguri	280.24
3. Darjeeling	254.21

Urbanization percent to Total	
1. Darjeeling	23.05
2. Jalpaiguri	9.59
3. Cooch Bihar	6.83

Villages (<200 persons) percent to Total	
1. Jalpaiguri	16.00
2. Darjeeling	15.00
3. Cooch Bihar	3.00

200-500 persons (percent)	
1. Darjeeling	25.00
2. Cooch Bihar	23.00
3. Jalpaiguri	6.00

Literacy Total (percent)	
1. Darjeeling	33.06
2. Jalpaiguri	24.00
3. Cooch Bihar	21.92

Female Literacy (percent)	
1. Darjeeling	23.23
2. Jalpaiguri	15.01
3. Cooch Bihar	11.50

Rural Literacy (percent)	
1. Darjeeling	26.01
2. Jalpaiguri	20.62
3. Cooch Bihar	19.23

Urban Literacy (percent)	
1. Cooch Bihar	58.59
2. Darjeeling	56.65
3. Jalpaiguri	55.89

Workers (percent)	
1. Darjeeling	36.89
2. Jalpaiguri	31.12
3. Cooch Bihar	27.61

Workers in Industry (percent)	
1. Darjeeling	4.86
2. Jalpaiguri	4.30
3. Cooch Bihar	3.79

Workers in Service (percent)	
1. Darjeeling	28.54
2. Jalpaiguri	17.42
3. Cooch Bihar	11.83

2. North East India

Density km^2 percent	
1. Tripura	148.54
2. Manipur	47.98
3. Meghalaya	44.98
4. Nagaland	31.24
5. Mizoram	15.75
6. Arunachal	5.59

200-500 persons (percent)	
1. Nagaland	33.85
2. Manipur	24.42
3. Meghalaya	23.84
4. Arunachal	13.89
5. Mizoram	.
6. Tripura	.

Rural Literacy (percent)	
1. Mizoram	51.36
2. Manipur	29.82
3. Tripura	27.13
4. Nagaland	23.69
5. Meghalaya	23.40
6. Arunachal	9.79

Urbanization percent to Total	
1. Meghalaya	14.54
2. Manipur	13.18
3. Mizoram	11.37
4. Tripura	10.44
5. Nagaland	9.95
6. Arunachal	3.67

Literacy Total (percent)	
1. Mizoram	53.80
2. Manipur	32.91
3. Tripura	30.97
4. Meghalaya	29.48
5. Nagaland	27.39
6. Arunachal	11.29

Urban Literacy (percent)	
1. Mizoram	72.48
2. Meghalaya	65.21
3. Tripura	63.98
4. Nagaland	60.70
5. Manipur	53.21
6. Arunachal	50.58

Villages (<200 persons) percent to Total	
1. Arunachal	80.89
2. Meghalaya	69.64
3. Manipur	49.97
4. Nagaland	34.79
5. Mizoram	16.16
6. Tripura	

Female Literacy (percent)	
1. Mizoram	46.75
2. Meghalaya	24.56
3. Tripura	21.20
4. Manipur	19.53
5. Nagaland	18.64
6. Arunachal	3.70

Workers (percent)	
1. Arunachal	56.44
2. Nagaland	50.76
3. Mizoram	45.61
4. Meghalaya	44.16
5. Manipur	34.56
6. Tripura	27.79

Workers in Industry (percent)	
1. Manipur	10.94
2. Tripura	3.54
3. Meghalaya	2.34
4. Nagaland	1.17
5. Mizoram	0.39
6. Arunachal	0.34

Workers in Service (percent)	
1. Tripura	19.90
2. Nagaland	19.59
3. Arunachal	19.07
4. Manipur	17.67
5. Meghalaya	15.79
6. Mizoram	15.24

INTERPRETATION AND USE OF LANDSAT IMAGERY FOR RESOURCE PLANNING IN THE HIMALAYA

P.N. GUPTA, IFS (Retired)

INTRODUCTION

The Indian Himalaya and Its Resources

The Indian Himalaya, with widths varying from 250 to 300 km, extend for about 2500 km from west to east and cover an area of 594,427 square kilometers, representing nearly 18 percent of the total area of the country (Table 1). Forests are reported to cover as much as 53.2 percent. Starting from about 300 meters altitudes rise with 92 peaks over 8000 meter above sea level. The major North Indian rivers rise here. The natural resources of soil, water (and snow), vegetation, minerals, energy sources and terrain are interrelated and changes affecting one have repercussions on others. The resources range from renewable to practically non-renewable,but none is unlimited and their use and conservation entail rational planning.

The Himalaya are geologically young and the environment is fragile. The extremes of climate, topography, relief, aspect and slope are some of the natural factors beyond human control (although slope can be modified to some extent) which have disturbed and damaged the environment and ecosystem. Unplanned land use, cultivation on steep slopes, overgrazing of pastures and wastelands by excessive but underfed livestock, shifting cultivation (mainly in Eastern India), lopping of broad- leaved species, road construction, mining and quarrying, over- exploitation of village or community forests, are a a few factors which have further accentuated ecological degradation. Erosion of topsoil is resulting in decreased production, not only where the soil has left, but also where it is deposited during floods. Speedy silting and sedimentation of reservoirs is a cause for alarm. Landslides and rockfalls are common and wind erosion takes place in the inner dry valleys. Springs are drying up and glaciers are reported to be receding.

The density of population per hectare of cultivated plus habitable land, which gives a more realistic picture than one based on the total geographical area, shows densities three to four times higher than in the plains. The resource base itself is gravely endangered, with land and forests most affected due to overpopulation and overstocking of livestock. Agricultural practices in rainfed, and particularly in unterraced, fields have been responsible for widespread and serious loss of topsoil, and agricultural nutrients have been depleted. The situation is getting worse in shifting cultivation (*Jhum*) areas.

Consequences of forest cover depletion and overgrazing are extremely serious. The three main categories of forests are reserved, village or community (protected/panchayat), and private

Table 1. **Area and Population of the Indian Himalaya by State**

S. No.	State	Geographical area (Km ^{2})	Reporting area (Km ^{2})	Forest %	Net area sown %	Population 1981	Rural %
1.	Jammu and Kashmir	2,22,236	45,230	61.4	15.6	5,987,389	78.9
2.	Himachal Pradesh	55,673	50,760	54.8	10.8	4,280,818	92.4
3.	Uttar Pradesh (8 hill districts)	51,112	48,800	46.7	17.1	48,835,712	80.9
4.	Sikkim	7,299	7,299	36.0	N.A	316,385	83.9
5.	West Bengal (Darjeeling)	3,075	3,110	38.1	32.1	1,016,177	85.7
6.	Assam	78,523	15,220	22.1	3.5	15,902,826	N.A
7.	Meghalaya	22,489	22,489	8.3	7.2	1,335,819	81.9
8.	Tripura	10,477	10,477	60.1	22.9	2,053,058	89.0
9.	Mizoram	21,087	20,920	62.0	1.9	493,757	75.3
10.	Manipur	22,356	22,110	27.2	6.3	1,420,953	73.6
11.	Nagaland	16,527	13,510	19.7	4.4	774,930	84.5
12.	Arunachal Pradesh	83,573	56,440	91.3	2.0	631,839	93.4
	Total:	5,94,427	38,206	53.2	9.7	43,049,663	

(Source-Planning Commission Task Force Report March 1982)

(Table 2). Village forests for the most part are no longer able to meet the needs of the people, and have turned into scrub and grassland. Overgrazing impedes regeneration, and fires to promote growth of grass also destroy young plants. As wood production decreases, people (mostly women and children) have to go farther from home for collection of firewood and fodder. Yet, firewood is and will continue to be the main energy source for the majority of the population.

The People and Their Needs

The region is a contact zone between the Indian subcontinent, the Tibetan Plateau and the Central Asian Mainland. This has had a profound effect on the sociocultural institutions of the people, their conditions of life and resource base on which they depend. The population of the region is about 43 million (Table 1) with a large number of ethnic groups at various stages of development, having very little in common. The sociocultural diversity and the differences of the natural resources and environments are so great that no uniform pattern of development can be adopted.

The basic human needs, apart from air, water and shelter, are food, fuel, fodder, fertilizer and fibre. Food supply in the region has to be supplemented from the plains because of the climatic conditions and limited availability of agricultural land in the mountains. Except in a few urban areas, wood and very small quantities of charcoal are the only source of fuel. Reported firewood production figures are misleading, as these do not include fuelwood removed free from the forests by the local people, for which no records are kept. However, the available export figures and estimated consumption of fuelwood are given in Table 3.

Energy needs of the people can only be met by regenerating the existing forests and creating man-made biofuel plantations or energy farms. With proper selection of species, this willresult in increased fodder and manure production. The species selected need to have, among others, the following properties: is fast growing; has high calorific value and highcropping potential; increases soil fertility; has leaves suitable for fodder and fertilizer; is suitable for watershed management and conducive to the general shaping of the environment.

Resource Planning Objectives in the Himalaya

The general objectives are to:

- Arrest and, as far as possible, reverse man-made ecological degradation (Protective)
- Rehabilitate badly eroded watersheds (Regenerative)
- Reduce soil erosion and water run-off to the maximum possible extent
- Conserve, maintain and improve tree growth and ground vegetation

Consistent with these goals are:

- To maximize production from all sources by afforesting denuded areas and wastelands adopting scientific land use and agronomic practices, improving and reducing livestock and adopting rotational grazing and controlled lopping
- To meet the fuelwood and fodder requirements of the people
- To develop and utilize non-conventional energy sources

Resource management in the Himalaya affects the downstream areas also. Since the effects follow natural rather than

Table 2: Statewise Forest Area of the Indian Himalaya by State (1981-82)

	Forest Area (Sq. Km.)						
State	Reserved	Protected	Unclosed	Others	Total	Encroach-unclosed Sq. Km.	Shifting Cultivation
1. Jammu and Kashmir	21,886	-	-		21,886	54	-
2. Himachal Pradesh	1,825	17,129	730	1	21142	167	-
3. Uttar Pradesh	23,720	10,070	20		34040	145	-
4. Sikkim	2,240	580,	-		2820	-	-
5. West Bengal	700*	426*	-	1,183*	143*	-	
6. Assam	17,074	-	2,759	10	30,708	1,312	4,900
7. Meghalaya	706	12		7	8,510	112	4,560
8. Tripura	3,862	2,058	-		5,920	15	1,360
9. Migram	6,312	1,647	5,240	3	16,629	-	4,800
10. Manipur	1,377	4,171	9,606	15,154	-	3,000	
11. Nagaland	286	518	210	1	2,876	10	6,570
12. Arunachal Pradesh	11,830	206	39,357		51,540	342	2,812

For entire state, as figures for hills districts alone not available.
(Source INDIA'S FORESTS 1984-FRI)

artificial boundaries, it is best to adopt watersheds as the units of integrated resource planning, monitoring and evaluation. This is true even in the case of rural energy planning, which has to consider the needs of the scattered inhabitants within a physical unit of land.

Resource Information Required

As the available knowledge and data base for the Himalaya is limited, fragmented, dispersed, sometimes outdated and on the whole, less than adequate, surveys are needed for:

- Water resources for human consumption, irrigation, power generation
- Snow for overall water resource assessment
- Soils (distribution, composition characteristics, degree of soil erosion and genesis of the various soil types) for determination of land capability or land use potential
- Vegetation (composition, distribution and degree of depletion of forests for rural energy

Table 3: Statewise Fuelwood Export (1980-81) and Estimated Annual Fuelwood Demand-Indian Himalaya

State	Fuelwood (000m) Exported	Estimated demand
1. Jammu and Kashmir	130	2994
2. Himachal Pradesh	134	2140
3. Uttar Pradesh	1041	2418
4. Sikkim	15	158
5. West Bengal	502*	2505
6. Assam	96	9951
7. Meghalaya	1	668
8. Tripura	174	1026
9. Mizoram	NA	247
10. Manipur		
11. Nagaland	NA	387
12. Arunachal Pradesh	24	316

Note: 1. Production figures are taken from FRI publications and these do not include firewood collected by local people.

2. Demand of fuelwood is calculated @ of 2.5 m 3 (1562.5 kg) per annum.

* For whole state

planning and for overall development, monitoring of changes, extent of pastures and wastelands, quantity of fodder and biomass produced)

- Mineral and fossil fuels (geological and geophysical mapping and exploration)
- Energy (geothermal, hydroelectric and meteorological data such as wind velocity, in addition to other renewable energy sources
- Crop (prediction of crop yield)

In the context of rural energy planning it is necessary to identify:

- Energy deficit areas
- Potential biofuel or energy plantation areas
- Sites for microhydel installations
- Sites for other non-conventional energy development

SURVEY AND DATA COLLECTION

Having decided upon the target area (e.g. energy deficit area), significant characteristics and parameters for which data are required may be noted. Technique and frequency of measurements, optimal level of spatial detail and sampling design, if necessary, are then decided upon. Available data from existing sources (such as Survey of India topographic maps, land records and forest working plans) is collected before undertaking new ground, air or satellite surveys. Ground surveys are the only method for detailed project work for very small areas but may not be practical for inaccessible and snowbound areas. Field checks are necessary for interpreted details and ground truth data is essential for interpretation of Landsat Imagery. Due to difficulty of timely procurement and high relief displacement, use of aerial photographs in the region will never have large-scale feasibility. At present, the only possibility is to use the Landsat Imagery as much as possible, supplemented with ground surveys of selected sample or priority areas.

THE LANDSAT SYSTEM

Satellites, Sensors and Imagery

The basic facts regarding the Landsat system are well known and need not be repeated. From the original video tape of satellite telemetry, the processing computers produce four different black and white corrected images on film, each of a 185 by 185 km scene, corresponding to the data registered on one of the four MSS bands. However, the 64 levels of intensity on the original tape are reduced in a black and white film to between 10 and 15 shades or levels of grey, which is the limit to which the human eye can distinguish. The grey levels for the same object often differ from band to band. By combining imagery of two or more bands, False Color Composites (FCC) are produced. Imagery (including the Thematic Mapper products for certain selected scenes) is available from the National Remote Sensing Agency, Hyderabad (NRSA). The Indian Himalaya are covered by about 46 scenes.

Arranged in order of increasing cost and sophistication, various methods of extracting information from remote sensing data are:

- Manual interpretation of standard photographic image - This is simple and uses inexpensive instruments. Photo enlargement and diazo processing are very useful.

- Manual interpretation aided by photographic enhancement - Image enhancement is a process of departing from the fidelity of an image so as to enhance particular features of interest by bringing out boundaries or edges of surface features. This is done by superimposing several images of the same scene taken on different dates or by assigning different colors to specific density ranges or slices. Zoom transferescope, color additive viewers and microdensitometers are used.

- Manual interpretation of special digitally enhanced photographic products

- Digital analysis of the Computer Compatible Tapes (CCT)- The digital data can be interpreted and analyzed. Though most expensive, it permits utilization of total information content of the original data and results can be in a variety of visual forms: statistical tables, graphs, digital maps, histograms, map overlays, annotated imagery or thematic maps.

Special Characteristics of Landsat Imagery and Data

Satellites have been the most prolific source of data since July 1972. The sensed data is available in digital form, permitting large data to be processed rapidly by computer to produce resource information desired for large areas in a relatively short time. Important data is obtained in infrared region which is beyond the range of camera systems. Thematic Mapper products are now available for selected scenes.

Resource	Capability of Landsat Regarding Imagery			Limitations
	Identification	Monitoring	Planning	
Water and Snow	Yes	Yes	Yes	Depth and quantities not available directly and dry streams can escape detection. For detailed project work of small areas, photographs are more useful.
Watershed	Yes	Yes	Yes	Very, very small watershed Boundaries boundaries cannot be delineated.
Geologic	Yes	Yes	Yes	Adds one more dimension Survey for understanding of mineral genesis.
Soils	Yes	Yes	Yes	Aerial photographs are useful for detailed work.
Land Use	Yes	Yes	Yes	Aerial photographs are useful for detailed work.
Forest and Vegetation	Yes	Yes	Yes	Aerial photographs are useful for detailed work.

The Imagery from a space platform has three very distinct and unique characteristics:

- The synoptic view coupled with uniform solar illumination from a near vertical perspective make it particularly useful for cartographic purposes, recognition of geologic features and vegetation patterns.
- Repetitive coverage provides an unequaled opportunity to monitor dynamic phenomena, such as changes in vegetation cover, hydrology, snow, land use, etc. Multi-date images can lead to more exact identification of static resource features.
- Uniformity, due to sun-synchronous orbit, makes it possible to have

image mosaics on a continental or country scale, and the overlay of scenes taken on different dates permits precise comparison.

USE OF LANDSAT IMAGERY

Remote sensing techniques provide the most rapid and cost- effective method for the inventory and monitoring of resources and land use over extensive areas (to be covered in low detail) together with detailed study of selected areas. The capabilities and limitations of Landsat data are given below. For best results, Computer Compatible Tapes analysis is necessary.

APPLICATION OF LANDSAT IMAGERY FOR RURAL ENERGY PLANNING

Identification and Mapping of Priority Areas

Generally, populated areas which are more than a reasonable walking distance away (say 5 km) from existing forests can be considered energy deficit areas. On band 5 (old) Landsat Imagery one can easily identify and map the existing forests: good (stratum 1.1) as well as degraded (stratum 1.2) Excluding snow- covered areas and alpine pastures, whatever non-forest area is seen on the imagery is an area of human and livestock concentration (Stratum II).

The present firewood supply to Stratum II areas is from the nearest existing forests of strata 1.1 and 1.2, and location of these strata clearly brings out the zone in which there is paucity of firewood. These can be mapped on scales varying from 1:250,000 to 1:1,000,000 depending upon the extent of area covered. As an example, if one were to consider the entire U.P. Himalaya, a 1:1,000,000 scale would be quite appropriate, while for a watershed of about 16,000 to 20,000 ha, 1:250,000 scale would serve the purpose. Once the location of villages with their population figures is marked on such maps (together with pilgrim routes and tourist spots), the position of areas where concentrated efforts are required can be more than clear to any energy planner. With edge-enhanced imagery and Computer Compatible Tapes analysis, more detailed information can be obtained.

Planning for Biofuel or Energy Plantations

Apart from availability of funds, the main constraints for any such program are the availability of suitable planting areas and people's willingness to cooperate. With the help of a map prepared at the identification stage, an estimate of potential planting areas may be obtained. With a similar study in the U.P. Himalaya, the estimated plantable area came to about 9,000 square kilometer. For 15,000 villages in the region, average planting area thus available per village is 60 ha. Planting can be done over 15-20 years, so that local people do not find difficulty parting with their grazing grounds and are able to get increased grass supply from closed areas. Similar estimates are possible for each watershed or sub-watershed. Forest and other relevant land use categories can be mapped for detailed work. Together with this planting, proper regeneration and controlled harvesting of existing forests, and protection and improvement of degraded forests, has also to be planned. Satellite imagery can be a useful tool in deciding the species to be planted if the planner is familiar with the terrain and locality factors.

Preliminary Selection of Microhydel Locations

The map prepared earlier can be supplemented by an overlay of the drainage system which can be mapped from Landsat Imagery (old Band 7). Land forms are quite clear on the imagery and with knowledge of local terrain one can select streams and a number of likely points for microhydel location, corresponding to the concerned priority area. Final choice has, however, to be made after ground survey. Since heights are not seen directly on the imagery, aerial photographs, if available, can serve the purpose better. If, however, the siting for microhydel has already been done, its location can be marked on imagery and an integrated overview of the situation, especially with respect to the likely impact on the environment, can be studied and examined. This is particularly true for big dams and hydel projects.

Development of Other Non-Conventional Energy Sources

Landsat Imagery clearly brings out the location of ridges and high points with which meteorological data on wind velocity can help in selection of windmill sites. Similarly, for solar energy installations one can select the sunny aspects and locations where maximum sunlight is likely to be available. However, use in all such cases relies on other available tools like aerial photography, topographic maps, and ground survey reports, and will depend upon the ingenuity and experience of the user.

CONCLUSION

Availability of Landsat Imagery, including Thematic Mapper products, has opened up vistas especially for integrated, multi-disciplinary and innovative resource and energy planning. In view of the environmental and ecological degradation, this is an urgent priority for the Himalaya. Interpretation of imagery and mapping can be done by experts in very little time. This gives a distinct advantage. Aerial photographs also afford this possibility and in some situations prove better, but in that case a much larger number of prints have to be handled and transfer of interpreted details onto base maps poses a serious problem due to extremes of altitudinal variations.

Maps with full details of extensive areas such as- river systems, land use energy deficient areas, and potential plantable areas, are extremely difficult to obtain with much accuracy, if not impossible, by any other method. If Landsat Imagery were not available, the U. P. Himalaya Watershed Management project could not have been conceived as it was, or have had the impact it has had in the development of fuel and fodder plantations. Such work, however, needs active participation of fairly senior level of planners/users. Also, one has to keep abreast of the latest developments in the field which are rapid and levant for rural energy planning. A great deal of work has yet to be done to fully exploit this potential.

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MICRO-EXPERIMENTS AND MACRO-APPLICATIONS FOR RURAL ENERGY PLANNING AND IMPLEMENTATION IN THE INDIAN HIMALAYA

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INTRODUCTION

Rapid dissemination of rural energy innovations to meet development needs is emerging as an important issue in the Indian Himalaya. Though generous subsidies have been instituted by the government to propagate these technologies, achievements have been poor in many states (GOI, DNES 1985). The failure rates and social, economic, and environmental impacts of these technologies are not well documented. Voluntary and participatory action for energy development are incapable of substantially replacing the present and potential role of government. However, by strengthening governmental abilities, complementary roles for such action may evolve.

Based on discussions with planners and implementers of rural energy projects, and visits by specialists to 17 developing countries, the problems of diffusion of biomass energy technologies have been reviewed (National Research Council 1984). Although not specifically oriented to the mountain region, this study led to the identification of opportunities, limitations, and recommendations for improving technology diffusion to meet development needs. The experience gained from the review is incorporated in the approach developed in this paper.

Major constraints for rapid diffusion of rural energy innovations in the Indian Himalaya are the heterogeneity in the local and site-specific physical, social, and economic characteristics and relative inaccessiblity to the towns and metropolises which are dynamic centers of energy innovations. Furthermore, a great deal of local experience regarding technical, economic, financial, cultural, and political aspects are required to make informed judgements about the potential for improving diffusion, major opportunities, constraints and above all, the contribution to regional energy budget and economy. These are very much lacking in the Indian Himalaya.

The methodology adopted is to visualize actors and processes which connect micro-experiments in the Himalaya with macro-applications for extension and implementation. This is presented as a feedback system (Figure 1). Further elements of these processes and the knowledge, experience, and data bases are discussed. This paper attempts to outline proposals for the implementation of micro-macro linkages in rural energy.

Actors and Processes related to the Micro Experiments and Macro Application for Rural Energy Planning and Implementation in the Mountains.

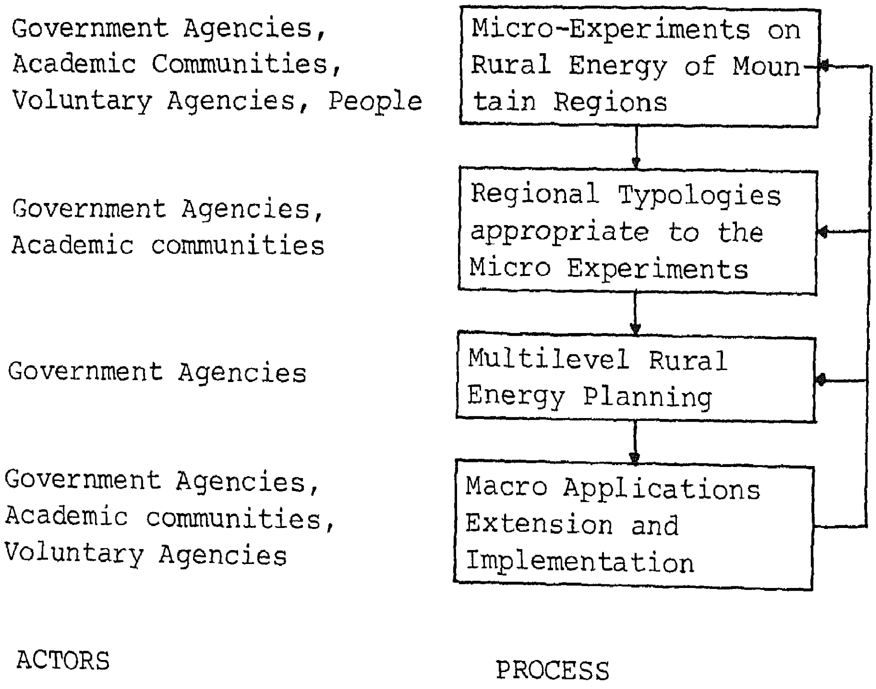
Government Agencies, Academic Communities, Voluntary Agencies, People
Micro-Experiments on Rural Energy of Mountain Regions
Government Agencies, Academic communities
Regional Typologies appropriate to the Micro Experiments
Government Agencies
Multilevel Rural Energy Planning
Government Agencies, Academic communities, Voluntary Agencies
Macro Applications Extension and Implementation
ACTORS
PROCESS

Figure: I

MICRO-EXPERIMENTS IN RURAL ENERGY

Micro-experiments in mountain area rural energy are trials carried out for improving industrial and agricultural production, and delivery of basic needs and their impact assessment to gain new knowledge regarding their applications. Physical, social, political, organizational, economic, financial, and environmental dimensions of these micro-experiments are important to establish one-to-one relationships between the interacting variables. Once statistically valid relations between variables are established, then they can be confidently applied where the environments of micro-experiments are similiar.

Applications of energy technologies require knowledge regarding the physical and socioeconomic aspects of mountain environments. For example, with rise in elevation, growth patterns and water requirements for crops vary considerably. This has not been adequately documented; therefore, it would not be possible to design a command area for windmill irrigation at a particular elevation in the Himalaya even if wind velocities were known. The Manual on Irrigation Water Management (GOI, Ministry of Agriculture and Irrigation 1979) has prioritized the plains, as have many engineering investigations. Inaccessibility, comparatively high expenditure on surveys, and lesser proportion of population served, have been constraints.

Typology of Micro-Experiments

Community studies, field surveys, and the Rural Energy Systems Research and Design Approach are useful tools for micro-experiments. The community study explores the intricate relations and unique interactions of critical variables in a particular setting, but the findings cannot be generalized. While field surveys can be designed to represent a population with known probabilities of error, the depth of understanding derived from the community study cannot be obtained by a field survey. Ideally, field surveys should be designed using insights derived from community studies. The Rural Energy Systems Research and Development Approach is analogous to Farming Systems Research and Development (FSR and D) of Shaner et al (1981). This pertains to a system defined by physical, biological, and socioeconomic setting, including the rural households' goals, access to resources, choice of productive activities, and management practices. On-farm research and analysis of FSR and D are analogous to micro-experiments.

Micro-experiments can give solid evidence of causality and then can be generalized from sample to the universe which it represents. Time-series experiments are very significant for the study of temporal change due to the application of energy technologies.

Before and After Approach

Villages in mountain environments can be classified and then random samples selected, where impact of existing energy flows are studied before and after the energy technologies are implemented. Based on the lessons learned, a policy of macro-application of energy technologies may be formulated.

In another approach, by random sample selection, experimental and control groups of villages are selected. Before and after observations are made on pairs of villages. Influencing factors that are not part of the experiment must be taken into account. "With significance tests, the probability can be assessed of any observed differences between experimental and control groups that are due to random causes." (White and Hursh-Ceasar 1976).

Rural Energy Systems Research and Development Approach

Researcher-managed trials. In researcher-managed trials, even though research is conducted in the field, many conditions and procedures are typical of those encountered in experimental stations or laboratories. The objective of the researcher-managed trial is to develop appropriate rural energy technologies for a specific group of villagers, and thereby perfect an approach of planning for macro-application. Characteristics of the research area, including types of beneficiaries and conditions, can be screened to assist the team in recognizing the gap between current supply and potential demand of energy by source and use. The team is able to work with the villagers, learn from them, and experiment with riskier and more difficult approaches, since the farmers' welfare is not at stake during experimentation.

The general methodological approach for researcher-managed trials is: selecting the microregion, identifying farmers/beneficiaries, planning experiments, monitoring progress, and analyzing and reporting experiments.

Villager-managed tests. These tests provide valuable insights to determine how new technologies fit into villagers' lives. Here the researcher acts as advisor and villagers as executors, with resources usually available to them. They are left to alter the approach. This provides the basis for modifying technologies and identifying areas for further research.

This method has several limitations:

- Experimental conditions cannot be controlled
- The number of experiments are limited
- Only simple energy technologies can be tested (complex ones require adequate infrastructural support which may not exist in the village)

Superimposed trials. Superimposed trials are researcher-managed experiments applied across a range of farmer-managed conditions. These trials may be single or multifactor experiments.

Analysis of Results

The purpose of analysis is to determine whether the new experiment is better than traditional methods, to measure social, economic, environmental, and quality of life changes, and to establish that these changes have not taken place by chance alone. The three types of experiments can be analyzed separately and in combination to derive the environmental, economic, financial, and organizational feasibility of micro-experiments and to understand villagers' reactions.

Wherever benefits and costs can be quantified into monetary units, the marginal rate of return can be computed. A high level of marginal return will generally interest farmers in change. As these levels decrease, farmers become less interested. At some point, they would no longer be willing to incur additional variable cost. We call this point the farmers' minimum acceptable return. Further sensitivity analysis can be utilized to test the stability of the results by looking into alternative possibilities for some of the other values affecting net benefit.

Micro-experiments can provide sufficient data to conduct economic and financial analysis. The best alternative economically may not be financially feasible. Energy technology in many cases is a long-term investment.

The Agricultural Science and

Technology Institute, Guatemala, has developed methods of assessing acceptability by defining an acceptability index (Hilderbrand 1979). The index is obtained by multiplying the percentage of farmers who adopt the new technology by the percentage of the unit so affected, divided by 100. Thus if 60 percent of the farmers adopt an energy technology and apply it to 50 percent of their crops, the acceptability index equals 30 (50 x 60 / 100). Any index larger than 25 is enough to justify for recommendation.

PROBLEMS ENCOUNTERED IN THE MACRO-APPLICATIONS OF MICRO-EXPERIMENTS IN RURAL ENERGY PLANNING

Replication of micro-experiments at the national level requires low research investment and suggests easy answers, and is thus attractive to the government rural energy planners. However, uninformed application ultimately leads to large amounts of time, money, and energy being wasted on ineffective programming (White and Hursh-Ceasar 1976). This paper suggests a strategy of staged, local adaptation.

Nature of Potential Rural Energy Technologies

Many of the rural energy technologies for mountain development involve specialized labor, materials, and capital. To reap the harvest of economy of scale, it may be necessary to mass produce these. The additional cost of distribution and marketing may proscribe affordability for the predominantly poor mountain people. Community-owned and community-operated rural energy technologies may be affordable, but the organizational input required to locate, manage, and finance such plants may require specially skilled community organizers and local leaders. Some energy technologies are commercialized, but the information regarding sources of suppliers, and requirements for labor and skill, may not be available locally.

Subsidies and credits are available for rural energy technologies. Richer farmers are the first to take advantage of such benefits; landless and marginal farmers have no access to institutional finances or availability of biomass energy resources at a constant supply rate.

Incremental innovations and preventive measures (e.g. insurance against failure of energy technologies to avoid a possible loss of a desired value in future) can be part of rural energy diffusion (National Research Council 1984). Likewise, when an energy innovation is changed by the adopter in the process of implementation, reinvention (adaptive technology) can be involved.

Variability of Mountain Environment

Changes in elevation and orientation of slopes create distinctly different Himalayan environments. Energy demands of the mountain people are related to the activity cycles and biotic and climatic environments. Large urban agglomerations in the valleys differ dramatically from the dispersed, semi-nucleated, and nucleated settlements in the mountains. The type of energy technology that can be integrated within towns and villages depends upon the morphology and typology of human habitation.

Problems of Lack of Infrastructure and Institutions

Availability of physical infrastructure lowers the cost of energy technologies in the mountains. The transportation and communication infrastructures to accelerate marketability are largely missing in the Himalaya.

No organization has been assigned the task of propagating rural energy technologies at the village level. Block development offices propagate biogas and other technologies on a limited scale, while fuelwood programs are looked after by the Forestry and/or Social Forestry Departments in India. The village-level workers are overburdened and it is doubtful they can provide the technically competent manpower, with effective communication capacity, and constantly updated training mechanisms necessary for rural energy extension. Individual agencies that give technological advice and subsidies are apex organizations with no grass roots-level cadre.

IDENTIFYING AREAS OF POTENTIAL SUCCESS FOR ENERGY TECHNOLOGIES

Regionalization for Rural Energy Planning

The goal of regionalization is to evolve an area-specific rural energy strategy by classifying the Himalaya into homogenous, polarized, and program regions. These approaches can be utilized for land assessment, fuelwood plantation, and classification of land areas into those currently unattractive for plantation efforts, areas heavily forested enough to receive secondary attention, and ones where immediate effort could make the difference between rapid deforestation and indefinitely sustained fuelwood yield.

However, it is easier to assign land use than to implement it. The quantity and quality of land available for fuelwood plantation are under competition from other uses. In areas of subsistence farming, land areas able to support heavy growth of trees will probably already be fully utilized for grazing or crop growing. In most cases, land available for tree plantation will be not only marginally suitable for agriculture, but also marginal for growing trees. Land-use planning which establishes beneficial combinations for farming, grazing, tree growing and making use of marginally productive land, may be one prerequisite for successful implementation of fuelwood plantation. Intercropping techniques where fuelwood plantation is used to provide beneficial windbreaks, shade, and soil enriching mulch is an alternate strategy. Fuelwood trees can be planted in combination with fruit and/or fodder trees and grasses for grazing. There are examples in which *leucaena leucocephala* have been intercropped for shade with coffee, cocoa, cinchona, pepper, and vanilla.

By map-sieving operations, it is possible to identify wasteland with potential for upgrading. Knowing the soil, rainfall, elevation, and climatic characteristics, it is possible to select weed trees which can grow in such wasteland. The planting of special, fast-growing fuelwoood species is especially attractive in areas with acute land shortages because the rates of wood production on a plantation can be more than five times the production of indigenous forests. The feasibility of committing land to tree growing alone will depend on village common land and government policy, and whether wealthy land owners can be persuaded to grow trees for the village on their land or to dedicate the required land area to a village plantation project. Regionalization in terms of homogenization gives a broad basis for fuelwood afforestation.

For biogas development in the hills, information on temperature variations, livestock census, population census, and settlement patterns are important. From the livestock census and animal dung production capacity and collection efficiency data, a weighted index of human and animal population ratio can be utilized to indicate favorable and unfavorable areas for biogas application. This can be mapped on an area for macro-application. Only where homesteads are scattered over hill terrain can individual biogas plants be utilized. In nucleated or semi-nucleated settlement areas, community biogas plants are a possibility. Community biogas plants give better access to landless and marginal farmers.

Mountain areas are generally characterized by low temperatures. The optimum temperature for methane-producing micro-organisms is 30°-35°C. Production of gas reduces with temperature unless other remedial measures are taken. Mean monthly temperature superimposed on a map can be utilized to determine areas feasible for biogas development.

Polarized regions are identified by functional linkages and flows. This represents a functionally interdependent system of settlements characterized by ·spatial interaction which can be measured by flow of commodities, persons, money, and information. These spatial interlinkages and inter-dependencies are critical for the spread of micro-experiments. Polarized regions can either be mapped as a flow diagram superimposed on transport networks or as straight lines where flows are plotted in scale to their volume connecting their origin and destinations. It can also be represented as an origin-destination matrix indicating, for example, number of telephone calls or number of buses running per day. Analysis of these data may be utilized to find out the hierarchy of settlements and their dependent villages.

The Village and Town Directory in the Indian census gives the list of services and facilities located within the settlement of significance for evolving a network of service centers for production, delivery, and servicing of renewable energy technologies. Existing institutions, like engineering colleges, agricultural colleges, polytechnics and local workshops, are nodes within the polarized regions which can be functionally utilized for macro-application of micro-experiments. Intermediate centers for production and services can be small towns having fabricating facilities. By proper locational planning, a system of service and production centers can be strengthened for rural energy application.

Program regions are areas having identical policy and implementing space for rural energy development. Policy for energy development can emanate from central government or state government. Policy incentives and politico-administrative structure for the macro-application of micro-experiments can be identified from program space to formulate suitable implementing strategies.

Multilevel Planning: The Current Status of Practice

For rational rural energy development, decentralization of the planning and decision-making power structure is required. India conducts planning at the national and state levels. Limited planning at the district and sub-district levels is now being conducted in an ad hoc manner, generally without legal basis or effective feedback mechanisms.

"The capabilities for decentralized planning have to be assiduously built up, the right procedures and suitable structure have to be evolved and necessary technical and administrative changes, including attitudinal changes, have to be brought about among the bureaucrats and the politicians. For decentralized planning to make headway, institutional mechanisms have to be made more broad-based with the active involvement of local resentatives and endowed with a greater autonomy in local decision making." (GOI. Planning Commission, 1984, para 3.4. and 3.8.)

A multilevel planning framework identifies the hierarchies of geographical space for decision making and action related to energy development. These are different, for example, for cooking stoves, community biogas, hydrams, and small hydels. Decision making and action space also differ in a program of substituting diesel pumpsets with windmills or electric pumpsets.

In multilevel planning there are opportunities to formulate the regional and subregional policies and strategies on the basis of local details at several levels (Sundaram 1980). This gives opportunities to relate plans for decision making at the appropriate financing and implementing levels; it relates decisions to the levels at which functionaries are empowered to make administrative, technical, and financial decisions.

While the strong point of multilevel planning is the local data base, the weak point is the inaccessibility or lack of knowledge of energy technology hardware and software appropriate to the local situation. Therefore, multilevel planning in conjunction with regionalization and selection of appropriate micro-experiments related to the regional typology gives the necessary base. Then these micro-experimental models can be modified to arrive at locational and siting decisions, and budgeting, implementing, and operating details.

Micro-experiments are useful in multilevel planning, especially from the point of view of manpower availability. There is a dearth of qualified planners to work below the state level in India. Micro-experiments will help them to simplify the planning task. A methodology for planning change in resource flow at the village cluster-level is given below. (Kumar 1985, 1986)

MULTILEVEL PLANNING PROCESS AT VILLAGE CLUSTER LEVEL

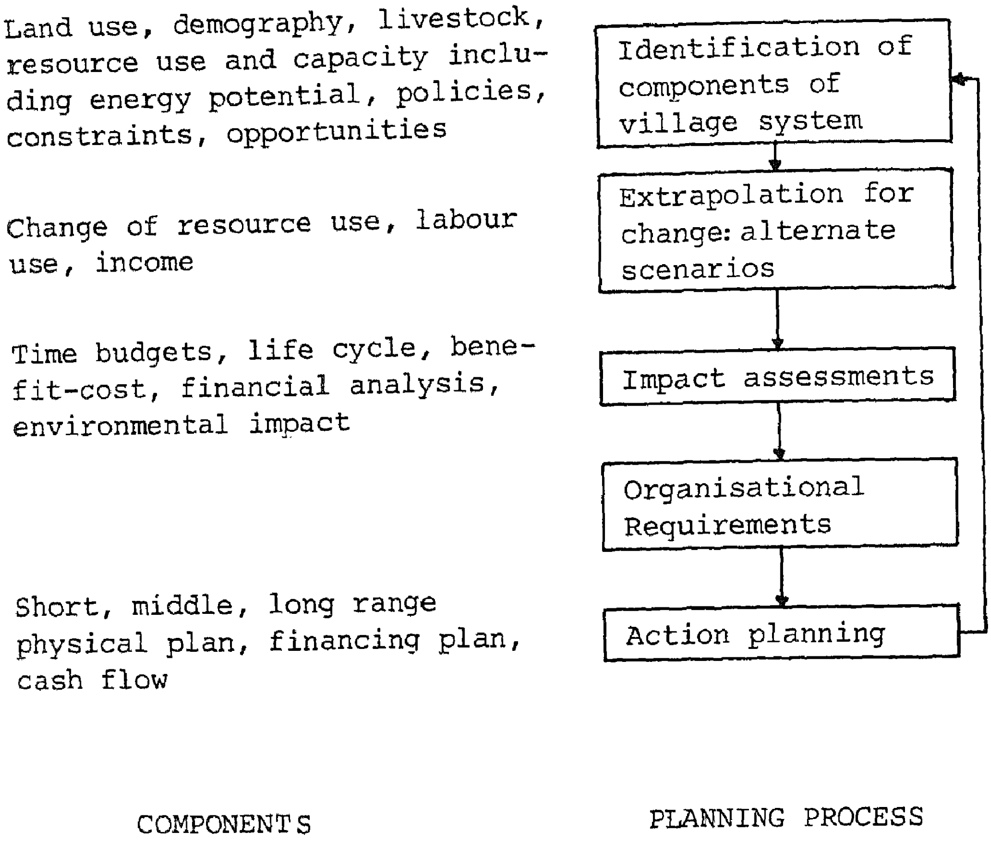
Land use, demography, livestock, resource use and capacity including energy potential, policies, constraints, opportunities
Change of resource use, labour use, income
Time budgets, life cycle, benefit-cost, financial analysis, environmental impact
Short, middle, long range physical plan, financing plan, cash flow
Identification of components of village system
Extrapolation for change: alternate scenarios
Impact assessments
Organisational Requirements
Action planning
COMPONENTS
PLANNING PROCESS

Figure: II

Data Required for Selection of Areas for Macro-Application

Data required for classifying areas for regionalization are mostly secondary data and maps. This is expected to cover the total environment which includes physical, biological, and socioeconomic environments, and production systems and land use. Data requirements can be further classified in terms of those required for delineating homogeneous regions, polarized regions and program regions. For homogeneous regions, physical and biological environment need to be defined spatially. This includes rainfall zones; maximum-minimum temperature zones; monthly wind velocity zones; number of sunny days; soil characteristics, including, physical, chemical, and hydrological conditions; topography, including elevation, land types like summit, side slopes, plateau, wet land, dry land, plains, bottom land, river terraces, land utilization and major crops; and irrigation status, including source, quality, and frequency of supply. Biological environment includes human and livestock census and phytogeography. For polarized regions, data on settlement services and facilities, transport networks and flow of people, goods, and communications is required. For program regions, state, district, block, *taluka* (revenue unit) boundaries, and boundaries of action of energy-related organizations and credit institutions are required.

For multilevel planning, both secondary and primary data are required. Secondary data may include performance characteristics of energy technologies, capital, and maintenance costs, and additional data on environment and sample household survey or census.

MACRO-APPLICATION AND EXTENSION OF ENERGY TECHNOLOGIES

The role of extension is the diffusion of the tested micro-experiments to the intended beneficiaries. This may involve communicating hardware and software to the rural communities, or acting as a catalyst to facilitate replicating tested energy technologies. Mao formulated his idea of decentralized diffusion and was successful in the massive dissemination of biogas technology in China. He wrote that one should "*take the idea of the masses (about their needs and possible solutions) and concentrate them (through study into more systematic innovations), then go to the masses and explain these ideas until the masses embrace them as their own, carry them out and persist in this on their own; then test correctness of these ideas in action" (Mao Tse-tung 1954*).

In India, the progressive, rich, and educated farmers get access to technology, technicians, credit schemes and are in a position to demonstrate application. The poor cannot take advantage of these benefits unless they are asisted by a well-organized extension system.

The role of extension service more specifically is to promote dependable rural energy technologies that effectively articulate countries' resource positions and development policies. They are expected to test and implement workable energy technologies and to suggest necessary changes in technology-support services, within the carrying limits of the resource and environment.

The methodology of rural extension has been improved considerably in the Training and Visit System (Benor and Harrison 1977). Farming Systems Research and Development has illustrated how a new technology can be quickly diffused to a large number of farmers. Here an Extension Specialist in the farming system instructs and supervizes extension agents in the new technology. Each of these agents transfers the technology to 10 local farmer leaders, and each one of them diffuses the technology to four groups of 25 farmers. Therefore, with the help of 10 extension agents and 100 local farmers, 10,000 households can be reached by one Extension Specialist in farming systems.

The Training and Visit System, which also incorporates effective feedback, reaches a similarly large number of people. However, in the Nepal Himalaya, the experience of implementing the Training and Visit (T and V) System, through the Hill Food Production Project, has proved that geographical and topographical factors do not allow faithful implementation of this model (Qamar 1985). Adjusting the model to suit the mountain condition creates drastic changes and leads to something different from the T and V, or FSR and D, models of extension.

State of Experience of Rural Energy Extension

India's experience with rural energy extension is limited but diverse. For example, Khadi and Village Industries Commission (KVIC) has one officer per district and one liasion officer at the *taluka* level who propagates biogas technology. Farmers can apply for loans and subsidies through the district officer. National banks provide loans and KVIC arranges suitable contractors if required to install the plant and service it for a year. KVIC makes payments to the contractor on behalf of the farmer and compiles information regarding the completion of the number of plants and the costs incurred and transmitted to the state level to release the subsidy for the farmers. The progress of KVIC implementation of biogas technology has been rather slow. Action For Food Production (AFPRO)--a non-profit, voluntary agency--has embarked on systematic promotion, transfer and extension of a low-cost fixed dome biogas plant known as the Janata Plant which has been developed by Gober Gas Research Station, Ajitmal, U.P. AFPRO launched this project in January, 1980, (Myles 1983, 1984) with the convening of a national seminar of grass roots-level agencies to promote biogas plants, and then constructed pilot demonstration Janata digesters, with varying soil conditions, to work out comparative costs and determine possible causes for failures. A team consisting of a supervisor, master masons, and masons was employed and given practical training for a month at headquarters before constructing "demonstration-cum-training Janata biogas plants" in different areas. There was widespread impact of these demonstrations. Several grass roots voluntary organizations requested technical assistance and guidance for construction.

In expanding this program, AFPRO came to the realization that the key to the program's success was a well-trained, professional mason who can read engineering drawings. Construction-cum-training workshops on Janata plants organized for selected professional masons have been given in states and union territories of India. Refresher training programs are planned in such a way that small groups of master masons would construct one to three plants under the close scrutiny of AFPRO technical experts. The Government of India adopted a multimodel and multiagency approach for biogas extension and was influenced by AFPRO's experience. AFPRO tried to identify competent grass roots-level voluntary agencies for extension of biogas technology. A five-year program was launched by AFPRO in 1983. In the first year, AFPRO was able to develop and involve 26 organizations. with 30 biogas centers, and in the second year, it covered 16 voluntary organizations with 20 biogas extension centers.

The Organization of Rural Poor (ORP) owns a well-equipped windmill workshop at Ghazipur. Once a request to install a windmill is received, ORP can institute a production-cum-training program at their workshop for local blacksmiths, fitters, and polytechnic or engineering graduates. These technicians and supervisors can install the windmill and undertake all servicing. ORP is more capable of undertaking small-scale jobs than large-scale dissemination.

The Government of India, state governments, and autonomous bodies continue to encourage such organizations for extension of rural energy technologies, and decentralization of implementation process. From their experiences, the government is able to formulate more workable extension approaches. Vertical functional linkages, grass roots-level organizational linkages, abilities to produce sufficient numbers of competent technicians to install and service the installations, and above all, adoption of the most appropriate technologies, are factors which help in the extension of some of these rural energy technologies.

General Problems Faced by Extension Activities in the Mountains

Rural energy extension in the Himalaya is a difficult task. The first problem faced by extension in rural energy is the lack of a proper holistic orientation. Propagation of any one energy technology without micro-experiments is not going to benefit the area or intended beneficiaries. An approach in which the energy system allows many options to meet the local needs more efficiently calls for extension agencies to deal with a package of rural energy technologies.

Extension is not generally integrated adequately with research establishments; neither can function effectively in isolation. Since extension agents work in a different domain, there is generally no scope for benefiting directly from the field insight of the research workers. From the farmer-managed and researcher-managed micro-experiments, extension workers can derive valuable insight for rapid propagation of energy technologies.

Training is often inadequate for extension workers. Knowledge of rapidly changing energy technologies including reinvention improves productivity and effectiveness in field operations. Theoretical knowledge should be adequately complemented with field training in fabrication.

There is a problem of extension agencies becoming highly centralized. Decisions made at the apex may be implemented at the grass roots-level with no questions asked. Extension can be more useful with constant feedback and changes of approach based on field adaptation.

A well-planned supervision and monitoring schedule is an integral part of rural energy extension. Generally, a low budget is provided for extension which results in low morale and inadequate reach. Inadequate training and extension aids limit effective extension. Extension can be effectively executed by private voluntary agencies or consulting firms in addition to the government organization.

Capability of Extension Agents in Rural Energy Planning and Development

At least two options are available to extend rural energy planning and development:

1. A group of extension agents, each specializing in one rural energy technology can work together in a village. This may be more difficult to organize and less feasible.

2. One extension agent who is capable of extending the entire spectrum of rural energy options may work in designated villages. For logistics and manpower, this is more feasible in mountain regions.

Such an energy extension agent requires several capabilities:

- Skilled understanding of the nature of macro-area related with appropriate micro-experiments
- Ability to select cooperative farmers, households, or beneficiaries
- Ability to conduct surveys, and monitor records and climatic data
- Ability to evaluate results of research in field conditions and form an integral part of the energy technology development process which is a combination of physical and social engineering
- Administrative ability to coordinate work of technicians and arrange delivery of credit and inputs for extension
- Ability to learn new energy innovations

Structure of Energy Extension System Proposed (Figure III)

In proposing an Energy Extension System structure, government machinery is not allowed to proliferate, but is limited to one district energy extension agent and one block energy extension assistant each, at the district and block levels. At state or regional levels, a Regional Rural Energy Extension Agency may exist, preferably along with Energy Development agencies. This agency shall employ, on a permanent or part-time basis, a group of professionals to continuously advise and train according to regional characteristics and needs. At the national level, a National Rural Energy Extension Agency may be located within the Department of Non-Conventional Energy Sources, to develop policies, educational programs, training programs, materials, and publications. A rural energy services and extension center may be located below block level at suitable market centers to serve the markets and their clusters of villages. This may be manned by a supervisor and group of technicians (master

Multilevel Planning Levels, Extension Function and Extension Structure for Rural Energy Planning, Extension and Development.

PLANNING LEVEL	EXTENSION FUNCTION	EXTENSION STRUCTURE
NATIONAL	To develop policies, educational programme, training programme materials and publications in all languages	National Rural Energy Extension Agency
REGIONAL (STATES)	Expert group to advice and train according to the regional characteristics and needs. Preparation of training and extension aids.	Regional Rural Energy Extension Agency
DISTRICT	Relates Extension to the needs of the district according to five year plans. Monitoring and Evaluation	District Rural Energy Extension Agent
BLOCK	Achieve annual plan target for rural energy extension, identify and service village leaders on rural energy. Monitoring and Evaluation	Block Energy Extension Assistant
SERVICE CENTRE	Establish rural energy service and extension centres, record keeping. Supervision of field activities. Research and extension supply of inputs.	Energy Service Centres managed by voluntary Agencies/Panchayat
VILLAGE	Village Experiments & Innovations in rural energy	Farmers

Figure: III

masons, fitters, etc.) who can undertake fabrications, servicing and recordkeeping. It can even run a nursery for tree plantation. These centers may be operated by local voluntary agencies or *panchayats* and have to be developed to be self-supporting within two to three years. Training and extension aids shall be provided continuously. Certain financial and technical sanctions for rural credit may be vested with these centers and proper vertical linkages with block energy extension assistants may be established. These service centers should keep linkages with the villagers and farmers, and propagate rural energy innovations by enlisting the support and participation of farmers.

IMPLEMENTATION (Figure IV)

The implementation process integrates both project and program approaches. Micro-experiments call for a project approach. Universities and technological institutions can be mobilized to conduct these micro-experiments in predetermined environments as and when needed. Regionalization, multilevel rural energy planning, and extension components of macro-application can be considered part of a program approach. This calls for creating new organizations in extension and strengthening existing or proposed multilevel planning systems with a focus on integrated resource development at the district level.

Rural energy extension needs to be organized as a separate activity within the existing structure at block, district, state, and national levels. Then this important activity will not be constrained by competing interests. The block rural energy extension assistant may have similar status and location to the agricultural extension worker in the block development office, but can be vertically integrated with a rural energy development agency. This is required because macro-application calls for interdisciplinary teamwork and development of special skills.

Evaluation studies may be conducted to compare the socioeconomic and environmental impacts with those visualized in the plans. These programs of action can be refined and extended by complementing, supplementing, or joining existing programs as well as through comparison with ongoing programs.

Every rural energy intervention should be considered an experiment, and all extension, experimentation on a large scale.

Institutionalisation of Micro Experiments and Macro Application for Rural Energy Planning and Implementation

PROGRAMME INPUTS

Creation of Special Institutions

Programme Funding

Programme Staffing

Programme Infrastructure

DELIVERY OF OUTPUTS

Hardware and software implemented, money spent, training

SERVICE OUTCOME

Increase in production, employment, income and better social, cultural and environmental quality.

PROGRAMME REDESIGN AND FEEDBACK

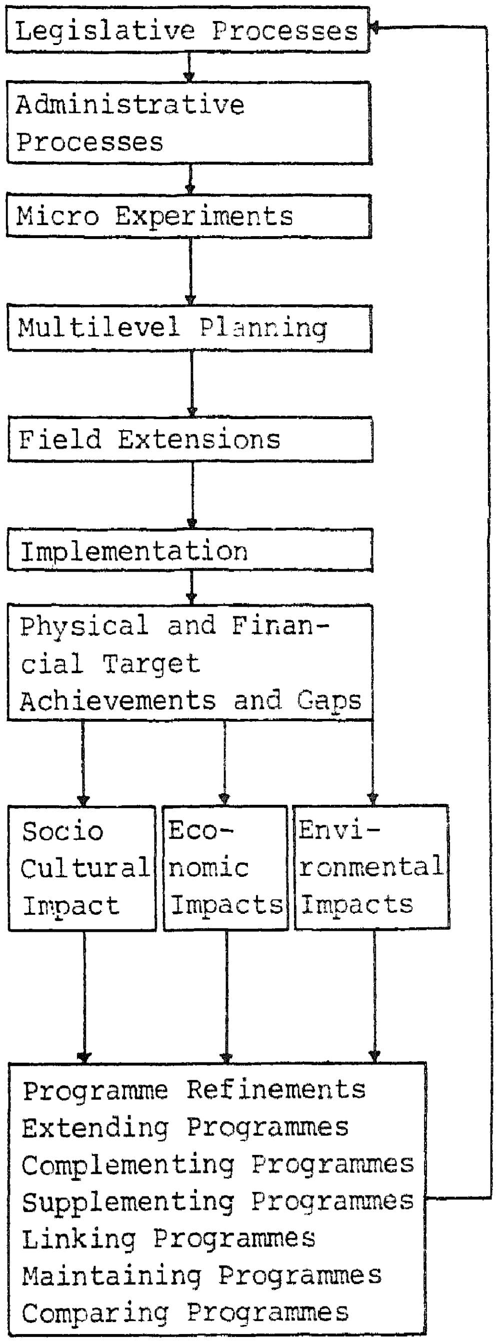

Figure: IV

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